BLUE PRINT

CHAPTER	VSAQ (2M)	SAQ (4M)	LAQ (8M)	Total Marks
1. Waves	–	–	1	8
2. Ray Optics & Optical Instruments	1	1	–	6
3. Wave Optics	–	1	–	4
4. Electric Charges and Fields	–	1	–	4
5. Electrostatic Potential	–	1	–	4
6. Current Electricity	–	–	1	8
7. Moving Charges & Magnetism	1	1	–	6
8. Magnetism and Matter	2	–	–	4
9. Electromagnetic Induction	–	1	–	4
10. Alternating Current	1	–	–	2
11. Electromagnetic Waves	1	–	–	2
12. Dual Nature of Radiation & Matter	2	–	–	4
13. Atomic Physics	–	1	–	4
14. Nuclear Physics	–	–	1	8
15. Semiconductor Electronics	1	1	–	6
16. Communication System	1	–	–	2
Total Number of Questions	**10**	**8**	**3**	**76**

1. **The Blue print is prepared according to the 'Model Question Paper' issued by B.I.E.**

2. **Please, note that, at times, the public question paper gets slight deviation from the above given Blue Print.**

01 Waves

LAQ (1) - 1 × 8 = 8M
SAQ (0) - 0 × 4 = 0M
VSAQ(0) - 0 × 2 = 0M
Total Marks = 8M

LONG ANSWER QUESTIONS (8 MARKS)

01. Explain the formation of stationary waves in stretched strings and hence deduce the laws of transverse waves in stretched strings ? **TS May 16, 18, Mar 19; AP May 16, 18**

Ans: **Stationary wave:** When two progressive waves of same amplitude and frequency travelling along the same straight line in opposite direction superimpose, a stationary wave is formed.

Formation of stationary wave: A string is fixed between two rigid supports.

It is excited perpendicular to its length to generate transverse waves which travel in opposite directions from point of excitation.

These transverse waves get reflected at rigid supports and overlap on each other to produce stationary waves.

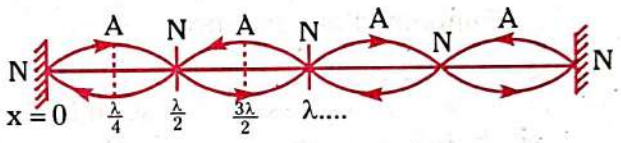
Due to superposition of the waves amplitude of the waves is modified to form nodes and antinodes. The amplitude of the resultant wave depends on phase.

Theory: Let, $Y_1 = a\sin(kx-\omega t)$ and $Y_2 = a\sin(kx+\omega t)$ be the displacements of the particle of the string due to incident and reflected waves from rigid supports. According to the principle of superposition, the resultant displacement is $Y = Y_1 + Y_2$.

$\Rightarrow Y = a\sin(kx-\omega t) + a\sin(kx+\omega t)$

$= a[\sin(kx-\omega t) + \sin(kx+\omega t)]$

$\Rightarrow Y = a[2\sin kx\cos\omega t]$



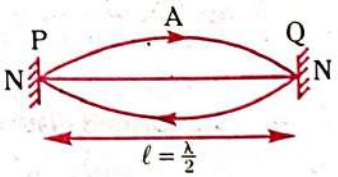
From $\sin(A-B)+\sin(A+B) = 2\sin A\cos B) \Rightarrow Y = 2a\sin kx\cos\omega t$.

The resultant displacement will be periodic in space with an amplitude, $A = 2a\sin kx$.

At position $x = 0, \frac{\lambda}{2}, \frac{2\lambda}{2}, \frac{3\lambda}{2}, \ldots$ nodes are formed and at $x = \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}, \ldots$ antinodes are formed.

Consider a string of length 'ℓ' stretched between two rigid supports P and Q. When the string is plucked, perpendicular to its length a transverse wave is generated which travels with a velocity of $v = \sqrt{T/\mu}$, where 'T' is tension in the string and 'μ' is linear density of the string. If the string vibrates in fundamental mode such that two successive nodes are formed at P and Q.

$\Rightarrow PQ = \frac{\lambda}{2} \Rightarrow \ell = \frac{\lambda}{2} \Rightarrow \lambda = 2\ell$.



But frequency, $n = \frac{v}{\lambda}$ —— (1)

Put $v = \sqrt{\frac{T}{\mu}}$ and $\lambda = 2\ell$ in eq.(1); we get, $n = \frac{1}{2\ell}\sqrt{\frac{T}{\mu}}$.

From above equation, laws of transverse vibration in string are obtained.

I law: The fundamental frequency of a vibrating string is inversely proportional to the length of the string, when tension in the string and linear density are kept constant.

$\therefore n \propto \frac{1}{\ell} \Rightarrow n\ell = k$, where T, μ remains constant.

II law: The fundamental frequency of a vibrating string is directly proportional to the square root of the tension, when length of string and linear density are constant.

$\therefore n \propto \sqrt{T} \Rightarrow \frac{n}{\sqrt{T}} = k$, where '$\ell$' and '$\mu$' remains constant.

III law: The fundamental frequency of a vibrating string is inversely proportional to the square root of linear density of the string when length and tension are kept constant.

$\therefore n \propto \frac{1}{\sqrt{\mu}} \Rightarrow n\sqrt{\mu} = k$, where '$\ell$' and 'T' remains constant.

02. Explain the formation of stationary waves in an air column enclosed in open pipe. Derive the equations for the frequencies of the harmonics produced.

TS May 17, Mar 16, 20; AP Mar 16, 17, 18, May 14, 17

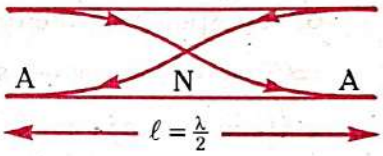
Ans: **Harmonics:** The frequencies which are integral multiples of fundamental frequency are 'Harmonics'.

Overtones: The frequencies higher than the fundamental frequency are known as 'Overtones'.

1) An organ pipe is a cylindrical tube having an air column. If both ends of the tube are open, it is known as an open pipe.
2) When a compressional wave (sound wave) is sent through an organ pipe, the wave gets reflected at the ends of the pipe.
3) These incident and reflected waves which are of the same frequency, travelling in the opposite directions superpose along the length of the pipe and form longitudinal stationary waves.
4) At the open end, where the particles of the medium are free to vibrate, always an antinode is formed. Here the two waves will be in phase and the particles will have maximum displacement.

Harmonics in open pipes:

1) The first harmonic or the fundamental frequency should atleast have an antinode at each end, with a node included between them. Therefore, the vibrating length (ℓ) of air column is equal to half the wavelength. i.e., $\ell = \lambda/2 \Rightarrow \lambda = 2\ell$.

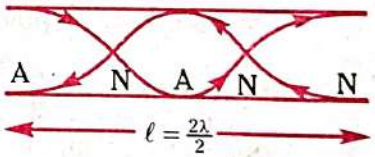


Fundamental frequency $n_1 = \frac{v}{\lambda}$,

where 'v' is the speed of sound in air. $n_1 = \frac{v}{2\ell}$ —— (1)

2) The second harmonic or the first overtone will have two nodes and three antinodes. If λ_2 is the corresponding wavelength, $\ell = \frac{2\lambda}{2} \Rightarrow \ell = \frac{\lambda}{2} + \frac{\lambda}{2}$.

First overtone

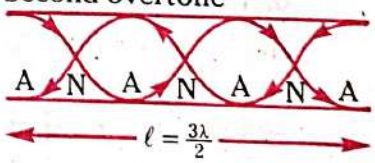


The corresponding frequency, $n_2 = \frac{v}{\lambda} = \frac{2v}{2\ell} = 2n_1$ —— (2)

3) Similarly, the third harmonic or second overtone will have three nodes and four antinodes as shown in the figure and if 'λ' is the wavelength,

$\ell = \frac{3\lambda}{2} \Rightarrow \lambda = \frac{2\ell}{3}$.

Second overtone



The frequency of the second overtone, $n_3 = \frac{3v}{2\ell} = 3n_1$ —— (3)

It can be observed that in the case of an organ pipe open at both ends all the harmonics can be formed. The frequencies of the higher harmonics can also be derived in the same way.

Conclusion: $n_1 : n_2 : n_3 ..... = 1 : 2 : 3 .....$.

03. How are the stationary waves formed in a closed pipe ? Explain the various modes of vibrations in a closed pipe and establish the relation between their frequencies.

TS Mar 15, 19, May 15; AP Mar 15, June 15, May 16, 17

Ans: 1) An organ pipe is a cylindrical tube having an air column. If one end is closed and the other is open, it is known as a closed organ pipe.

2) When a compressional wave (sound wave) is sent through an organ pipe, the wave gets reflected at the ends of the pipe. These incident and reflected waves which are of the same frequency, travelling in the opposite directions are superimposed along the length of the pipe and form longitudinal stationary waves.

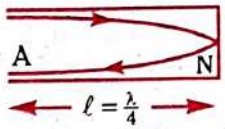
3) At the open end, where the particles of the medium are free to vibrate, always an antinode is formed. Here the two waves will be in phase and the particles will have maximum displacement.

4) When reflection takes place at the closed end, the two waves will be in opposite phase and hence the superposition of the waves gives zero displacement to the particles. Therefore, always a node is formed at the closed end.

Harmonics in closed pipes:

1) The first of the harmonics in a closed pipe should have a node at the closed end and an antinode at the open end, the length of the pipe (ℓ) vibrating in one fourth of the wavelength. i.e., $\ell = \frac{\lambda}{4} \Rightarrow \lambda = 4\ell$.

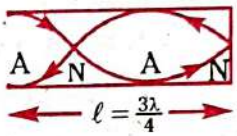
Fundamental frequency



The fundamental frequency, $n_1 = \frac{v}{\lambda} = \frac{v}{4\ell}$ ——— (1)

2) The next possible harmonic with two nodes and two antinodes is the third harmonic, the length of the pipe becomes equal to $\frac{3^{th}}{4}$ of the wavelength (λ) i.e., $\ell = \frac{3\lambda}{4}$, where '$\lambda$' is the wavelength of the third harmonic $\lambda = \frac{4\ell}{3}$.

First overtone



The frequency of the third harmonic or first overtone is given by,

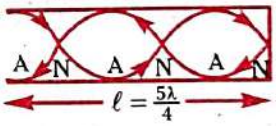
$n_3 = \frac{v}{\lambda} = \frac{3v}{4\ell} = 3n_1$ ——— (2)

3) Similarly, the next overtone in the closed pipe is only the fifth harmonic. It will have three nodes and three antinodes between the closed end and the open end of the pipe.

The length 'ℓ' of the pipe adjusts itself to $\frac{5}{4}$ of the wavelength (λ) i.e., $\ell = \frac{5}{4}\lambda$

and the frequency of this second overtone is given by $n_5 = \frac{v}{\lambda}$

Second overtone



$= \frac{5v}{4\ell} = 5n_1$ — (3) $\left(\because \lambda = \frac{4\ell}{5}\right)$

The frequencies of the higher harmonics can be derived in the same way.

It can be observed that in the case of closed organ pipes only odd harmonics are possible.

Conclusion: $n_1 : n_3 : n_5 .... = 1 : 3 : 5 : .....$

04. What are beats ? Obtain an expression for the beat frequency. Where and how are beats made use of ?

Ans: The phenomenon in which two sound waves of nearly equal frequencies travelling along the same direction superimpose on each other, the intesity of the resultant wave at the given point in the medium becomes maximum (waxing) and minimum (waning) periodically is called beats.

Let the displacement equtions of two waves haivng frequencies ω_1 and ω_2 be $y_1 = a\sin\omega_1 t$ and $y_2 = a\sin\omega_2 t$.

From superposition principle $y = y_1 + y_2$ resultant displacement

$y = a\sin\omega_1 t + a\sin\omega_2 t = a(\sin\omega_1 t + \sin\omega_2 t)$

$\Rightarrow y = a \times 2\cos\frac{(\omega_1 - \omega_2)t}{2}\sin\frac{(\omega_1 + \omega_2)t}{2}$ $\quad \therefore \left[\sin A + \sin B = 2\sin\frac{A+B}{2}\cos\frac{A-B}{2}\right]$

$\Rightarrow y = 2a\cos\frac{(\omega_1 - \omega_2)t}{2}\sin\frac{(\omega_1 + \omega_2)t}{2}$

Here, $A_R = 2a\cos\frac{(\omega_1-\omega_2)t}{2}$ is called resultant amplitude of beat wave.

Resultant amplitude on intensity is maximum when

$$\cos\frac{(\omega_1-\omega_2)t}{2} = \pm 1 = \cos N\pi \quad [\because N = 0,1,2,3,.....]$$

$$\frac{2\pi(n_1-n_2)t}{2} = N\pi \Rightarrow t = \frac{N}{n_1-n_2}.$$

$\therefore$ Time interval between two maxima (or) minima is $\Delta t = \frac{1}{n_1-n_2}$.

But reciprocal of time interval is called Beat frequency $n = \frac{1}{\Delta t} \Rightarrow n = n_1 - n_2$.

Importance of Beats:

1) Beats are used in detecting dangerous gases in mines.
2) Beats are used to produce special effects in cinematography.
3) The phenomenon of beats can be used to determine an unknown frequency of a note.
4) These are also used to tune an instrument to give a note.

05. What is Doppler Effect ? Obtain an expression for the apparent frequency of sound heard when the source is in motion with respect to an observer at rest.

Mar 14; AP Mar 16, 20; TS Mar 17, 18

Ans: **Doppler effect:** The apparent change in frequency of sound observed due to relative motion between the observer and the source of sound is called Doppler effect.

Source Moving: Observer Stationary

Let 'O' be the position of observer who is at rest $(v_0 = 0)$.

Let at a time $t = 0$, the source 'S' is at a position S_1. Let v_s be the velocity of source.

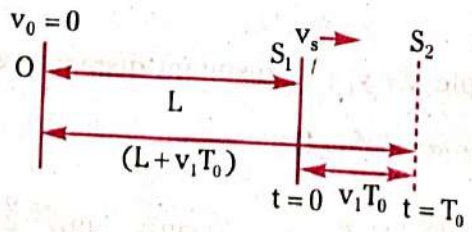
Let 'v' be the velocity of sound wave and T_0 be its time period.

Let initially the distance between the source and observer is 'L' and emits a crest at point S_1.

Let t_1 be the time taken by the first crest to reach the observer. $\therefore t_1 = \frac{L}{v}$.

At time $t = T_0$, the source has moved a distance of v_sT_0 and is at point S_2, located at a distance $(L + v_sT_0)$ from the observer.

At S_2, the source emits a second crest. Let t_2 be the time taken by the second crest to reach the observer. $\therefore t_2 = T_0 + \frac{(L+v_sT_0)}{v}$.



Similarly, at a time $t = nT_0$, the source emits $(n+1)^{th}$ crest. It reaches the observer in a time $t_{n+1} = nT_0 + \frac{(L+nv_sT_0)}{v}$.

∴ The time interval between the arrival of the first crest and $(n+1)^{th}$ crest is

$$t_{n+1} - t_1 = nT_0 + \frac{(L + nv_sT_0)}{v} - \frac{L}{v} = nT_0 + \left(1 + \frac{v_s}{v}\right).$$

Therefore, the observer receives 'n' crests and the observer records the period of the wave as

$$T = \frac{nT_0[1 + (v_s / v)]}{n} \Rightarrow T = T_0\left(1 + \frac{v_s}{v}\right).$$

In terms of frequency, we have $\nu = \nu_0\left(1 + \frac{v_s}{v}\right)^{-1}$.

By using binomial expansion and by neglecting higher powers, the above equation can be approximated as $\nu = \nu_0\left(1 - \frac{v_s}{v}\right)$ — (1)

Here, $\nu < \nu_0$ that is apparent frequency is less than original frequency.

For a source approaching the observer, we replace v_s by $-v_s$.

Therefore, we get $\nu = \nu_0\left(1 + \frac{v_s}{v}\right)$ — (2)

Here, $\nu > \nu_0$ that is apparent frequency is greater than original frequency.

06. What is Doppler shift ? Obtain an expression for the apparent frequency of sound heard when the observer is in motion with respect to a source at rest. **AP June 15**

Ans: **Doppler shift:** The difference between apparent frequency heard by the observer and actual frequency produced by the source is called Doppler shift.

Expression for the apparent frequency of sound heard when the observe is in motion with respect to a source at rest:

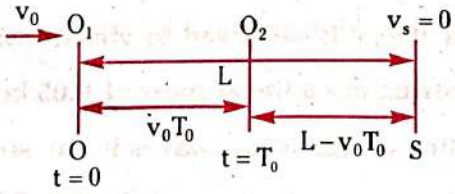
Let S be the position of source which is at rest $(v_s = 0)$.

Let 'v' be the velocity of sound wave and T_0 be its time period.

Let 'O' be the observer located at O_1 at a time $t = 0$.

Let v_0 be the velocity of the observer.

As shown in figure, let initially the distance between the source and observer is 'L'.



Let the observer is having a detector which detects every time when a wave crest reaches the observer.

At $t = 0$, if the source emits the first crest, then the time taken by the first crest to reach the observer is $t_1 = \frac{L}{v + v_0}$.

At $t = T_0$, the observer is at position O_2 by covering a distance (v_0T_0). Now, if the source emits the second crest, the time taken by the second crest to reach the observer is $t_2 = T_0 + \frac{L - v_0T_0}{v + v_0}$.

Similarly, at time $t = nT_0$, the source emits $(n+1)^{th}$ crest. Time taken by the observer to hear $(n+1)^{th}$ crest is $t_{n+1} = nT_0 + \frac{L - nv_0T_0}{v + v_0}$.

The time interval between arrival of first crest and the $(n+1)^{th}$ crest is

$$t_{n+1} - t_1 = nT_0 + \frac{L - nv_0T_0}{v + v_0} - \frac{L}{v + v_0} = nT_0 + \frac{L}{v + v_0} - \frac{nv_0T_0}{v + v_0} - \frac{L}{v + v_0} = nT_0\left(\frac{v}{v + v_0}\right).$$

The detector detects the time period as T which is given by

$$T = \frac{nT_0[v/(v + v_0)]}{n} \Rightarrow T = T_0\left(\frac{v}{v + v_0}\right).$$

In terms of frequency we have, $\nu = \nu_0\left(\frac{v + v_0}{v}\right)$.

Here, $\nu > \nu_0$ that is apparent frequency is greater than original frequency.

If the observer is moving away from the stationary source, then we replace v_0 by $-v_0$.

Therefore, we get $\nu = \nu_0\left(\frac{v - v_0}{v}\right)$.

Here, $\nu < \nu_0$ that is apparent frequency is less than original frequency.

PROBLEMS

07. A steel wire 0.72 m long has a mass of 5.0×10^{-3} kg. If the wire is under a tension of 60 N, what is the speed of transverse waves on the wire ? **AP Mar 19; EXAMPLE PROBLEM**

Sol: Mass per unit length of the wire, $\mu = \frac{5.0 \times 10^{-3}\ kg}{0.72\ m} = 6.9 \times 10^{-3}\ kg\ m^{-1}$, Tension, $T = 60\ N$.

The speed of wave on the wire is given by, $v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{60\ N}{6.9 \times 10^{-3} kg\ m^{-1}}} = 93\ ms^{-1}$.

08. A stretched wire of length 0.6 m is observed to vibrate with a frequency of 30 Hz in the fundamental mode. If the string has a linear mass of 0.05 kg m^{-1}, find

a) the velocity of propagation of transverse waves in the string,

b) the tension in the string. **TS May 16; AP May 18; SOLVED PROBLEM**

Sol: Length of wire, $\ell = 0.6\ m$; fundamental frequency, $n = 30\ Hz$, $\mu = 0.05\ kg\ m^{-1}$.

a) Velocity of propagation of wave in the string, $v = n\lambda = n(2\ell) = 30 \times 2 \times 0.6 = 36\ ms^{-1}$.

b) Tension in the string, $v = \sqrt{\frac{T}{\mu}} \Rightarrow T = v^2\mu$

$\Rightarrow T = (36)^2 \times 0.05 = 36 \times 36 \times 0.05 = 64.8\ N$.

09. A steel cable of diameter 3 cm is kept under a tension of 10 KN. The density of steel is 7.8 g cm^{-3}. With what speed would transverse waves propagate along the cable ?

Sol: Diameter of cable, $d = 3\,cm$, Tension, $T = 10\,KN$, Density of cable, $\rho = 7.8\,g\,cm^{-3}$

$$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{T}{(m/\ell)}} \quad \left(\rho = \frac{m}{v} = \frac{m}{\pi r^2 \ell}\right)$$

$$\Rightarrow v = \sqrt{\frac{T}{\rho \pi r^2}} = \sqrt{\frac{10^4}{7.8\times10^3 \times 3.14(1.5)^2 \times 10^{-4}}} = \frac{10^2}{1.5\sqrt{7.8\times0.314}} \approx 42.6\ ms^{-1}.$$

10. A pipe 30.0 cm long is open at both ends. Which harmonic mode of the pipe resonates a 1.1 kHz source ? Will resonance with the same source be observed if one end of the pipe is closed ? Take the speed of sound in air as 330 ms^{-1}. **TS Mar 15; EXAMPLE PROBLEM**

Sol: The first harmonic frequency is given by, $\nu_1 = \frac{v}{\lambda_1} = \frac{v}{2L}$ (open pipe)

where 'L' is the length of the pipe. The frequency of its n^{th} harmonic is $\nu_n = \frac{nv}{2L}$, for $n = 1,2,3....$ (open pipe).

For $L = 30\,cm$, $v = 330\,ms^{-1}$, $\nu_1 = \frac{1\times330}{0.6} = 550\,Hz$, $\nu_2 = \frac{2\times330}{0.6} = 1100\,Hz$.

Clearly, for a source of frequency 1.1 kHz the air column will resonate at ν_2, i.e., second harmonic. Now, if one end of the pipe is closed, the fundamental frequency is $\nu_1 = \frac{v}{\lambda_1} = \frac{n\times v}{4L}$

where $n = 1,3,5,.....$.

$\nu_1 = 275\,Hz$; $\nu_2 = 3\nu_1 = 825\,Hz$; $\nu_3 = 5\nu_1 = 1375\,Hz$.

$\therefore$ Hence, with closed end resonance is not possible with the given source.

11. A closed organ pipe 70 cm long is sounded. If the velocity of sound is 331 ms^{-1}, what is the fundamental frequency of vibration of the air column ?

Mar 14; AP Mar 17, 18, May 17; TS Mar 19; SOLVED PROBLEM

Sol: Closed organ pipe length, $\ell = 70\,cm$, Velocity of sound, $v = 331\,ms^{-1}$.

Fundamental frequency, $n = \frac{v}{4\ell} = \frac{331}{4\times70\times10^{-2}} = 118.2\,Hz$.

12. A pipe 30 cm long is open at both ends. Find the fundamental frequency ? Velocity of sound in air is 330 ms^{-1}. **TS Mar 15, 20**

Sol: Given length of open pipe $\ell = 30\,cm = 30\times10^{-2}\,m$.

Fundamental frequency $n = \frac{v}{2\ell} = \frac{330}{2\times30\times10^{-2}} = 550\,Hz$.

13. A open organ pipe 85 cm long is sounded. If the velocity of sound of 340 ms^{-1}, what is the fundamental frequency of vibration of the air column ? **TS Mar 16, 20**

Sol: Given length of open pipe $\ell = 85\,cm = 0.85\,m$, $V = 340\,ms^{-1}$, $n = ?$

Fundamental frequency $n = \frac{V}{2\ell} = \frac{340}{2\times0.85} = \frac{340}{1.7} = 200\,Hz$.

14. Two organ pipes of lengths 65 cm and 70 cm respectively are sounded simultaneously. How many beats per second will be produced between the fundamental frequencies of the two pipes ? (Velocity of sound $= 330\ ms^{-1}$) **TS Mar 20, SOLVED PROBLEM**

Sol: Two organ pipes of length, $\ell_1 = 65$ cm & $\ell_2 = 70$ cm ; Velocity of sound, $v = 330\ ms^{-1}$.

Number of beats produced per second, $\Delta n = \frac{v}{2\ell_1} - \frac{v}{2\ell_2} = v\left(\frac{1}{2\ell_1} - \frac{1}{2\ell_2}\right)$

$$\Rightarrow \Delta n = 330\left(\frac{1}{2\times65\times10^{-2}} - \frac{1}{2\times70\times10^{-2}}\right) = \frac{(140-130)\times330}{(130\times140)\times10^{-2}} = \frac{3300\times100}{18200} \approx 18\ Hz.$$

15. A rocket is moving at a speed of $200\ ms^{-1}$ towards a stationary target. While moving, it emits a wave of frequency 1000 Hz. Some of the sound reaching the target gets reflected back to the rocket as an echo. Calculate

a) the frequency of the sound as detected by the target and

b) the frequency of the echo as detected by the rocket. **AP Mar 16; EXAMPLE PROBLEM**

Sol: a) The observer is at rest and the source is moving with a speed of $200\ ms^{-1}$. Since, this is comparable with the velocity of sound, $330\ ms^{-1}$.

Since, the source is approaching a stationary target, $v_0 = 0$.

We have, $n' = n_0\left(1 - \frac{v_s}{v}\right)^{-1} \Rightarrow n = 1000\times\left(1 - \frac{200}{300}\right)^{-1} \cong 2540\ Hz$.

b) The target is now the source (because it is the source of echo) and the rocket's detector is now the detector or observer (because it detects echo). Thus, $v_s = 0$.

The frequency of the sound emitted by the source (the target) is n', the frequency intercepted by the target and not n_0. Therefore, the frequency as registered by the rocket is

$$n' = n\left(\frac{v+v_0}{v}\right) = 2540\times\left(\frac{200+330}{330}\right) = 4080\ Hz.$$

*** THE END***

02 Ray Optics & Optical Instruments

LAQ (0) - 0 × 8 = 0M
SAQ (1) - 1 × 4 = 4M
VSAQ(1) - 1 × 2 = 2M
Total Marks = 6M

SHORT ANSWER QUESTIONS (4 MARKS)

01 **Define focal length of a concave mirror. Prove that the radius of curvature of a concave mirror is double its focal length.**

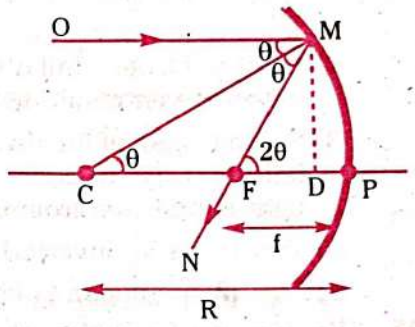
AP Mar 17, 19, May 16, 18

Ans: **Focal length:** The distance between pole and principal focus is called focal length.

Consider a concave mirror of small aperture with pole, focus and centre of curvature at points P, F and C respectively.

Let a ray OM parallel to principal axis falls on mirror at 'M'. Now the reflected ray MN will pass through focus 'F'. Here, CM is normal to the mirror at 'M'.

Let 'θ' be angle of incidence. MD is perpendicular to principal axis.



From triangle MCP $\tan\theta = \frac{MD}{CD}$,

when 'θ' is small $\tan\theta \simeq \theta = \frac{MD}{R}$ ——— (1)

From triangle MFP $\tan 2\theta = \frac{MD}{FD}$,

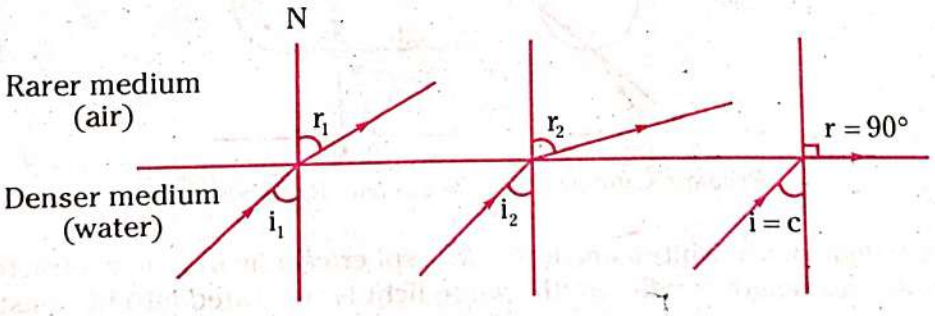
when 2θ is small $\tan 2\theta \simeq 2\theta = \frac{MD}{F}$ ——— (2)

Put (1) in (2), $2 \times \frac{MD}{R} = \frac{MD}{f}$. $\therefore 2f = R$ (or) $f = \frac{R}{2}$.

02 **Define critical angle. Explain total internal refection using a neat diagram.**

May 14; AP Mar 15; TS Mar 15, 18, May 17

Ans: **Critical angle (C):** When light travels from denser medium to rarer medium, the angle of incidence for which angle of refraction is $90°$ is called critical angle.



When light ray enters from denser medium to a rarer medium, it bends away from normal, if the angle of incidence is further increased, the angle of refraction also increases and at $i = c$, the refracted ray grazes the interface $(r = 90°)$

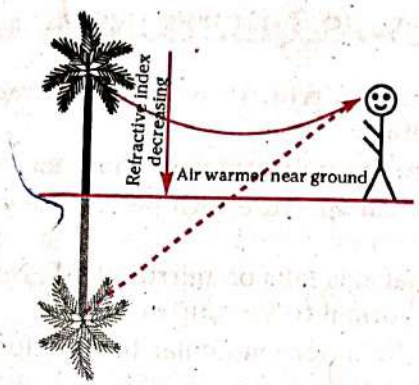
From Snell's law $\mu_0 \times \sin i = \mu_R \times \sin r \Rightarrow \mu \times \sin c = 1 \times \sin 90° \Rightarrow \mu = \frac{1}{\sin c}$.

Total internal reflection: When light ray travel from denser medium to rarer medium, the angle of incidence in the denser medium is greater than the critical angle, then the light ray totally reflected back into the denser medium. This phenomenon is called total internal reflection.

03. Explain the formation of a mirage. **TS Mar 19, May 18; AP Mar 16**

Ans: **Mirage:** It is an optical illusion observed in desertes (or) on roads on hot summer days. It is due to total internal reflection.

1) On hot summer days the air near the ground becomes hotter. Hence, it becomes less dense. Therefore the refractive index of hot air near the ground decreases.



2) Light ray from a tall object passes through air with decreasing refractive index towards the ground. As a result, light bends away from normal and undergoes total internal reflection.

3) So, the angle of incidence near the ground exceeds critical angle. But, to a distant observer light appears to come from somewhere below the ground. So, the observer assumes that light is reflected from the ground light by a pool of water.

4) This forms an inverted image of tall object and causes optical illusions to the observer.

5) This phenomenon is known as mirage.

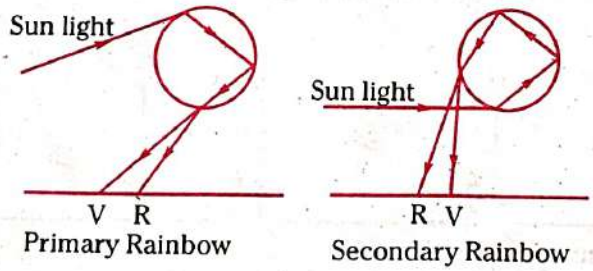
04. Explain the formation of a rainbow. **AP May 15, Mar 15, 20; TS Mar 20**

Ans: 1) Rainbow is due to dispersion of white sunlight by water drops in atmosphere.

2) It is due to combined effect of dispersion, refraction and reflection.

3) To observe a rainbow one part of the sky should have sunshine and in other part it should be raining.

4) Rainbow can be seen when looked away from sun on a rainy day.



5) As shown in figure when white sunlight enters a spherical rain drop it is refracted. As refracted for different wavelength is different the white light is separated into its constituent colours.

6) As the wavelength of red is longer it is bent by small angle. As the wavelength of violet is shorter it is bent by a large angle. The deviation of other colours will take place in between red and violet.

7) When the component rays fall on inner surface of water drop at angle greater than critical angle (48°) it is internally reflected.

8) As the reflected component rays come out they are refracted again increasing the separation. This is how a rainbow is formed.

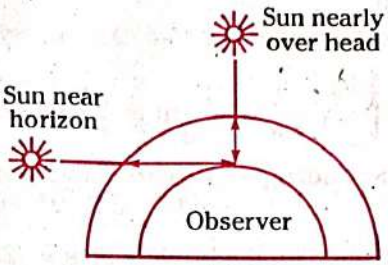
9) When two refractions and one internal reflection take place, a rainbow with red at the top and violet at the bottom is formed. It is called primary rainbow.

10) When there are two refractions and two internal reflections a rainbow with violet at the top and red at the bottom is formed. It is called secondary rainbow.

05. Why does the setting sun appear red ? **Mar 14; AP June 15; TS May 15, Mar 17**

Ans: The reddish appearance of sun is explained by Rayleigh scattering.

Scattering: When light is incident on small particles it is absorbed by them. This absorbed light is then sent in all directions. This phenomenon is called scattering.



Rayleigh showed that the amount of scattering is inversely proportional to the fourth power of wave length, when size of molecule $a << \lambda$ i.e., intensity of scattered light $\propto \frac{1}{\lambda^4}$. This is called Rayleigh scattering.

During sunrise or sunset when the sun is at the horizon, the sun rays have to pass through a large distance in the atmosphere to reach earth, hence suffer maximum scattering.

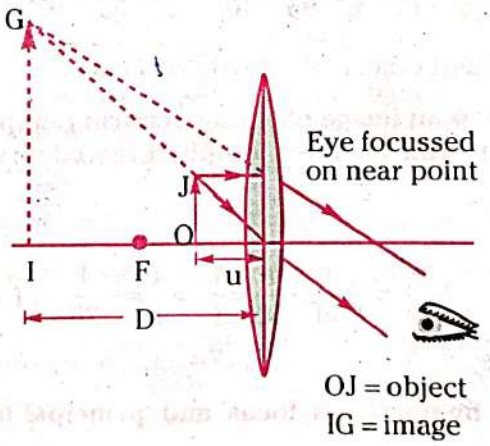
As scattering $\propto \frac{1}{\lambda^4}$, shorter wavelengths are scattered most, leaving the longer wavelength i.e., red to reach the eye. Hence, sun appears reddish during sunrise and sunset.

06. With a neat labelled diagram explain the formation of image in a simple microscope.

AP Mar & June 15, May 16, Mar 18; TS Mar & May 16

Ans: A simple microscope is converging lens of small focal length.

In a simple microscope, object is to be kept at a distance less than or equal to focal length of lens and eye is very close to lens. Object placed within the focal plane of the lens forms an erect, magnified and virtual image between object and infinity. (On the same side of object). This position is called near point (D = 25cm).



For relaxed vision, object is kept at F and image is at infinity. The position is called far point.

When the object is at a distance less than focal length 'f' of the lens, the rays after passing through the lens diverge away. When these diverging rays are produced back they meet between object and infinity i.e., image is formed between object and infinity (generally at near point) as shown in figure.

PROBLEMS

07. Two lenses of power −1.750 D and +2.250 D respectively, are placed in contact. Calculate the focal length of combination ? **AP Mar 20; SOLVED PROBLEM**

Sol: Power, $P = \frac{1}{f(m)}$ (or) $P = \frac{100}{f(cm)}$

$P = P_1 + P_2 = -1.75 + 2.25 = 0.50\ D$; $f = \frac{1}{P} = \frac{1}{0.50} m = \frac{1}{50} \times 100 = 200\ m$.

08. What focal length should the reading spectacles have a person for whom the least distance of distinct vision is 50 cm ? **TS Mar 19, EXAMPLE PROBLEM**

Sol: Distance of normal vision is 25 cm. So, if a book is at $u = -25$ cm ; its image should be formed at $v = -50$ cm .

From $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{f} = \frac{1}{-50} - \frac{1}{-25} \Rightarrow \frac{1}{f} = \frac{-1}{50} + \frac{1}{25} \Rightarrow f = 50$ cm (convex lens).

VERY SHORT ANSWER QUESTIONS (2 MARKS)

09. What are the laws of reflection through curved mirrors ?

Ans: **Laws of reflection:**

1) The angle of reflection is equal to the angle of incidence.

2) The incident ray, reflected ray and the normal to the reflecting surface at the point of incidence lie in the same plane.

10. A concave mirror of focal length 10 cm is placed at a distance 35 cm from a wall. How far from the wall should an object be placed so that its real image is formed on the wall ? **TS May 19**

Ans: Given, focal length, $f = -10$ cm (concave)

Image distance, $v = -35$ cm , Object distance from mirror, $u = ?$

From mirror formula, $\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \Rightarrow \frac{1}{u} - \frac{1}{35} = \frac{-1}{10} \Rightarrow \frac{1}{u} = \frac{1}{35} - \frac{1}{10} = \frac{-25}{35 \times 10} = -\frac{1}{14} \Rightarrow u = -14$ cm .

$\therefore$ Distance between wall and object, $d = 35 - 14 = 21$ cm .

11. A concave mirror produces an image of a long vertical pin, placed 40 cm from the mirror, at the position of the object. Find the focal length of the mirror. **TS Mar 17, 20**

Ans: Given, $v = u = -40$ cm , $f = ?$

From mirror formula, $\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \Rightarrow -\frac{1}{40} - \frac{1}{40} = \frac{1}{f} \Rightarrow \frac{1}{f} = -\frac{1}{20} \Rightarrow f = -20$ cm .

$\therefore$ Focal length is 20 cm.

12. What do you understand by the terms 'focus' and 'principal focus' in the context of lenses ?

Ans: **Focus:** Focus of a lens is any point through which rays of light are converged.

Principal Focus: It is a point on the principal axis of a lens at which image of an object at infinity is formed. A lens will have two focal points on either side.

13. Define focal length and radius of curvature of a concave lens ?

Ans: Focal length of a concave lens is the distance between optical centre and principal focus of the lens.

Radius of curvature of a concave lens is the radius of the sphere from which the lens is cut.

14. Define 'power' of a convex lens. What is its unit ? **AP May 16; Mar 17; TS Mar & May 16**

Ans: The power of a convex lens is defined as the tangent of the angle by which a lens converges a beam of light falling at unit distance from the optical centre. (or)

It is reciprocal of focal length, $P = \frac{1}{f}$. S.I. unit of power of lens is dioptre (D).

15. The focal length of a concave lens is 30 cm. Where should an object be placed so that its image is $\frac{1}{10}$ of its size ?

Ans: Given focal length, $f = -30$ cm ; We know $m = \frac{v}{u} \Rightarrow \frac{1}{10} = \frac{v}{u} \Rightarrow v = \frac{u}{10}$.

From lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{10}{u} - \frac{1}{u} = -\frac{1}{30} \Rightarrow \frac{9}{u} = -\frac{1}{30} \Rightarrow u = -9 \times 30 = -270$ cm .

16. A small angled prism of 4° deviates a ray through 2.48°. Find the refractive index of the prism. **AP June 15, Mar 18, 19**

Ans: Given angle of prism, $A = 4°$; Angle of deviation, $D = 2.48°$; Refractive index, $\mu = ?$

For small angled prism, $D = (\mu - 1)A \Rightarrow \mu = \frac{D}{A} + 1 = \frac{2.48}{4} + 1 = 0.62 + 1 \Rightarrow \mu = 1.62$.

17. What is dispersion ? Which colour gets relatively more dispersed ? **Mar & May 14**

Ans: The phenomenon of splitting of white light into its constituent colours is known as dispersion.

Violet colour is relatively more dispersed.

18. What is myopia ? How can it be corrected ?

TS Mar 15, 17, May 17, June 15; AP Mar & June 15

Ans: The light from a distant object converges at a point infront of the retina. So the distant object is not clearly visible. This defect is called myopia or short sightedness. Myopia is corrected by using spectacles having divergent lens (concave lens).

19. What is hypermetropia ? How can it be corrected ? **AP Mar 16, May 17; TS Mar 18**

Ans: The light from the near object converges at a point behind the retina. So the near objects are not clearly visible. This defect of eye is called hypermetropia. Hypermetropia can be corrected by using spectacles having convergent lens (Convex lens).

20. What is optical density and how is it different from mass density ? **AP & TS 17**

Ans: Optical density is the ratio of speed of light in two media. Refractive index (μ) is a measure of optical density.

The mass density of a substance is the mass per unit volume of the substance. It is physical property of the substance.

***** THE END*****

03 Wave Optics

LAQ (0) - 0 × 8 = 0M
SAQ (1) - 1 × 4 = 4M
VSAQ(0) - 0 × 2 = 0M
Total Marks = 4M

SHORT ANSWER QUESTIONS (4 MARKS)

01. Explain Doppler effect in light. Distinguish between Red shift and Blue shift.

TS May 15, Mar 16, 19; AP June 15, Mar 16, May 18

Ans: **Doppler's effect in light:** To an observer on the earth, the light from a star moving towards him appears with high frequency or less wavelength. Similarly, the apparent wavelength is high in the case of star moving away from him. This change in apparent frequency or wavelength of light due to relative motion of the source is called Doppler effect.

The Doppler shift is given by $\frac{\Delta\nu}{\nu} = \frac{v_{radial}}{c}$, where v_{radial} is component of source velocity along the line joining the observer and the source and c is velocity of light.

v_{radial} is positive when source is moving away from the observer.

The Red shift: When a light source is moving away from an observer with a velocity 'v', then frequency observed by the observer is less than the frequency emitted by the source (or) the apparent wavelength increases i.e., shift towards the red end of the spectrum.

The Blue shift: When a light source is approaching an observer with a relative velocity 'v', then the apparent frequency observed by the observer is more than frequency emitted by the source (or) the apparent wave length decreases i.e., shift towards the blue end of the spectrum.

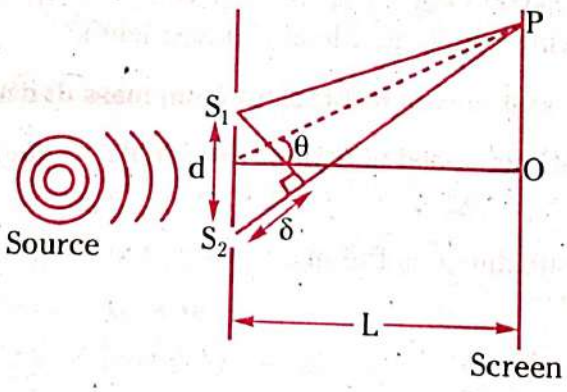
02. Derive the expression for the intensity at a point where interference of light occurs. Arrive at the conditions for maximum and zero intensity. **AP Mar 15, 16, 18; TS Mar 15, May 18**

Ans: 1) Let us consider two slits S_1 and S_2 are separated by a distance 'd'.

2) 'O' is the mid point between two slits.

3) Consider a point 'P' on the screen. The waves from S_1 and S_2 have same wave length 'λ', amplitude 'a' and are in same phase.

4) The difference between the distances 'δ' is called the path difference. Let the corresponding phase difference is 'ϕ'.



Let $y_1 = a\sin\omega t$, $y_2 = a\sin(\omega t + \phi)$

The resultant displacement 'y' of the waves,

$$y = y_1 + y_2 = a\sin\omega t + a\sin(\omega t + \phi) \Rightarrow y = a\sin\omega t + a[\sin\omega t\cos\phi + \cos\omega t\sin\phi]$$

$\Rightarrow y = (a\sin\omega t + a\sin\omega t\cos\phi) + a\cos\omega t\sin\phi$

$\Rightarrow y = a\sin\omega t[1+\cos\phi] + a\sin\phi\cos\omega t$ —— (1)

Let $a(1+\cos\phi) = R\cos\alpha$ —— (2), $a\sin\phi = R\sin\alpha$ —— (3)

Substitute (2) and (3) in (1), $y = R\sin\omega t\cos\alpha + R\sin\alpha\cos\omega t \Rightarrow y = R\sin(\omega t+\alpha)$

'y' is the resultant displacement due to waves at P.

$(2)^2 + (3)^2 \Rightarrow R^2[\cos^2\alpha + \sin^2\alpha] \Rightarrow R^2 = a^2[1+1+2\cos\phi] = a^2[2+2\cos\phi] = 2a^2[1+\cos\phi]$

$\Rightarrow R^2 = 2a^2 \cdot 2\cos^2\left(\frac{\phi}{2}\right) = 4a^2\cos^2\left(\frac{\phi}{2}\right) \Rightarrow R = 2a\cos\left(\frac{\phi}{2}\right)$.

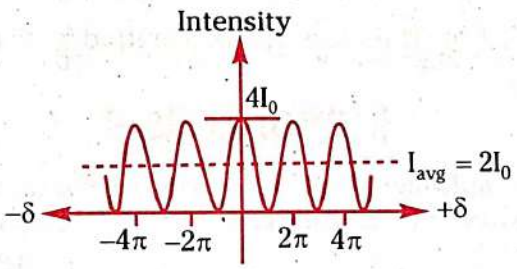
But, 'I' is the resultant intensity at 'P, $I \propto R^2$. $\therefore I = 4a^2\cos^2\left(\frac{\phi}{2}\right)$

Conditions for zero intensity: If $\phi = \pi, 3\pi, 5\pi, \ldots (2n+1)\pi$, $\cos^2\left(\frac{\phi}{2}\right) = 0 \Rightarrow I = 0$ (minimum).

03. Does the principle of conservation of energy hold for interference and diffraction phenomena ? Explain briefly. **May 14; AP May 16, Mar 17, 20**

Ans: Yes, the principle of conservation of energy holds good for the phenomenon of interference and diffraction.

In case of interference, the energy will disappear at the position of dark bands and this energy will be appeared at the position of bright bands. Thus energy remains constant. So principle of conservation of energy holds good for interference.



In interference and diffraction, redistribution of energy takes place. The energy of dark band is transferred to bright band. Thus average energy of waves remains same. There is no loss or gain of energy due to formation of dark and bright bands in interference and diffraction of light, thus they do not violate law of conservation of energy.

In diffraction phenomenon interference will takes place. Therefore, principle of conservation of energy also holds good for diffraction.

04. How do you determine the resolving power of your eye ? **May 14; AP Mar 17, 19; TS Mar 18, 20**

Ans: You can estimate the resolving power of your eye with a simple experiment.

Make black stripes of equal width separated by white stripes; see figure here.

All the black stripes should be of equal width, while the width of the intermediate white stripes should increase as you go from the left to the right. For example, let all black stripes have a width of 5 mm. Let the width of the first two white stripes be 0.5 mm each, the next two white stripes be 1 mm each, the next two 1.5 mm each etc. Paste this pattern on a wall in a room or laboratory, at the height of your eye.

Now watch the pattern, preferably with one eye.

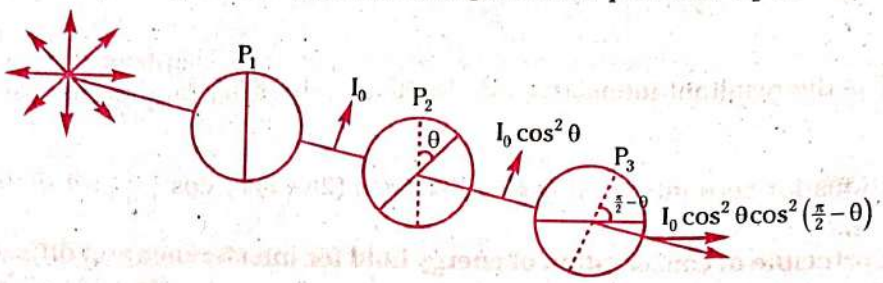
By moving away or closer to the wall, find the position where you can just see some two black stripes as separate stripes. All the black stripes to the left of this stripe would merge into one another and would not be distinguishable. On the other hand, the black stripes to the right of this would be more and more clearly visible.

Note the width 'd' of the white stripe which separates the two regions, and measure the distance 'D' of the wall from your eye. The d/D is the resolution of your eye.

05. Discuss the intensity of transmitted light when a polaroid sheet is rotated between two crossed polaroids ?

Ans: Let I_0 be the intensity of polarised light after passing through the first polariser P_1.

Then the intensity of light after passing through second polariser P_2 will be $I = I_0\cos^2\theta$.



where 'θ' is the angle between pass axes of P_1 and P_2.

Since, P_1 and P_3 are crossed, the angle between the pass axes of P_2 and P_3 will be $\left(\frac{\pi}{2}-\theta\right)$.

Hence the intensity of light emerging from P_3 will be $I = I_0\cos^2\theta\cos^2\left(\frac{\pi}{2}-\theta\right)$

$I = I_0\cos^2\theta\sin^2\theta = \left(\frac{I_0}{4}\right)\sin^2 2\theta$. Therefore, the transmitted intensity will be maximum when $\theta = \frac{\pi}{4}$.

PROBLEMS

06. Two slits are made one millimeter apart and the screen is placed one meter away. What is the fringe separation when blue-green light of wave length 500 nm is used ?

AP June 15; EXAMPLE PROBLEM

Sol: Fringe spacing $= \frac{D\lambda}{d} = \frac{1\times5\times10^{-7}}{1\times10^{-3}}\text{m} = 5\times10^{-4}\text{m} = 0.5\,\text{mm}$.

VERY SHORT ANSWER QUESTIONS (2 MARKS)

07. Explain Brewster's law ?

AP June 15; TS May 16

Ans: When unpolarised light is incident on transparent surface, at a particular angle of incidence called Brewster angle i_p, the reflected light wave is totally polarised and is perpendicular to the refracted light wave.

'The tangent of the angle of polarization (i_p) is numerically equal to the refractive index μ of the reflecting medium'. $\mu = \tan i_p$.

08. What is Malus law ?

TS May 17

Ans: "The intensity of the polarized light transmitted through the analyser is proportional to square of cosine of the angle between the plane of transmission of analyser and the plane of transmission of polarizer".

$I = I_0\cos^2\theta$ where, I_0 = intensity of the polarised light after passing through the polariser.

θ = angle between the planes of transmission of the analyser and the polariser.

*** THE END***

04 Electric Charges and Fields

LAQ (0) - 0 × 8 = 0M
SAQ (1) - 1 × 4 = 4M
VSAQ(0) - 0 × 2 = 0M
Total Marks = 4M

SHORT ANSWER QUESTIONS (4 MARKS)

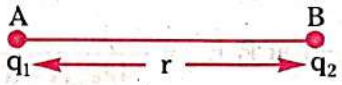
01. State and explain Coulomb's inverse square law in electricity.

Mar 14; AP May 17, 18; TS Mar 17

Ans: **Coulomb's Law:** The force of attraction or repulsion between two stationary point electric charges is directly proportional to the product of the magnitudes of the two charges and is inversely proportional to the square of the distance between them. The force acts along the straight line joining the two charges.

Explanation: Let us consider two stationary point charges q_1 and q_2 separated by a distance 'r' from each other.

Let 'F' be the force of the attraction or repulsion between the two stationary charges.



According to Coulomb's law, $F \propto q_1 q_2$ and $F \propto \frac{1}{r^2}$. So, $F \propto \frac{q_1 q_2}{r^2}$

$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$, where ε_0 is called permittivity of free space.

Here, $\frac{1}{4\pi\varepsilon_0} = 9\times10^9 \text{ Nm}^2\text{C}^{-2}$ and $\varepsilon_0 = 8.85\times10^{-12}\text{C}^2/\text{Nm}^{-2}$ or farad/metre.

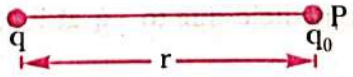
Force between two charges depends on the nature of the medium. In a medium, $F = \frac{1}{4\pi\varepsilon}\frac{q_1 q_2}{r^2}$, where ε = permittivity of medium.

02. Define intensity of electric field at a point. Derive an expression for the intensity due to a point charge.

AP Mar 16

Ans: **Intensity of electric field (E) at a point:** Intensity of electric field at any point in an electric field is defined as the force experienced by a unit positive charge placed at that point. $\vec{E} = \frac{\vec{F}}{q_0}$.

Electric field strength due to a point charge: Consider a point charge 'q'. Electric field will exist around that charge. Consider a point 'P' in that electric field at a distance 'r' from the given charge. A test charge q_0 is placed at P.



Force acting on q_0 due to 'q' is, $F = \frac{1}{4\pi\varepsilon_0}\frac{qq_0}{r^2}$.

Intensity of electric field at that point is equal to the force experienced by a test charge q_0, placed at that point.

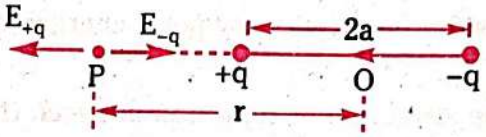
Intensity of electric field, $E=\frac{F}{q_0}=\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$ here ε_0 = permitivity of free space.

In any medium, intensity of electric field, $E=\frac{1}{4\pi\varepsilon}\frac{q}{r^2}$, here ε = permitivity of medium.

SI unit of intensity of electric field newton/coulomb.

03. Derive an expression for the intensity of electric field at a point on the axial line of a dipole.
AP May 16, Mar 16, 17, 18, 19; TS Mar & May 16

Ans: **The intensity of electric field at a point on the axial line of a dipole:** Consider an electric dipole consisting of two charges +q and −q separated by a distance 2a. The dipole moment of dipole is $p=q\times 2a$. Let 'P' be the point on the axial line of the dipole at a distance 'r' from its centre 'O' as shown in figure.



Electric field intensity due to −q at P, $\vec{E}_{-q}=-\frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\hat{p}$, where $\hat{p}$ is the unit vector along the dipole axis (from −q to q).

Electric field intensity due to +q at P, $\vec{E}_{+q}=\frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}\hat{p}$

The total field at 'P' is $\vec{E}=\vec{E}_{+q}+\vec{E}_{-q}=\frac{1}{4\pi\varepsilon_0}\left[\frac{q}{(r-a)^2}-\frac{q}{(r+a)^2}\right]\hat{p}=\frac{1}{4\pi\varepsilon_0}\frac{4qar}{(r^2-a^2)^2}\hat{p}$.

If $r>>a$, $\vec{E}=\frac{1}{4\pi\varepsilon_0}\frac{4qa}{r^3}\hat{p}\Rightarrow\vec{E}=\frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}\hat{p}$ $[\because P=q\times 2a]$.

04. Derive an expression for the intensity of the electric field at a point on the equatorial plane of an electric dipole.
AP Mar 15; TS Mar 20

Ans: **Intensity of electric field on the equatorial line:** Consider an electric dipole consisting of two charges +q and −q separated by a distance 2a. Let the dipole moment of electric dipole is 'p' and it is placed in a uniform electric field 'E' with an angle 'θ' as shown in figure.

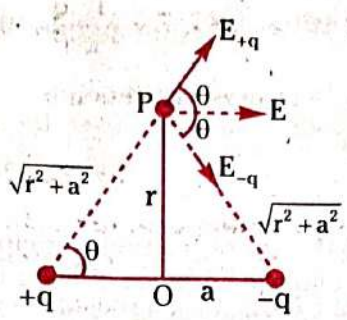
Let 'P' be the point on the equatorial line of the dipole at a distance 'r' from its centre as shown in figure.

Magnitude of intensity of electric field due to +q at P, $E_{+q}=\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2+a^2}$.

Magnitude of intensity of electric field due to −q at P, $E_{-q}=\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2+a^2}$.

Let us resolve $\vec{E}_{+q}$ and $\vec{E}_{-q}$ into two mutually perpendicular directions. The components normal to the dipole axis cancel away. The components $E_{+q}\cos\theta\,\hat{p}$ and $E_{-q}\cos\theta\,\hat{p}$ along the dipole axis add up.

So, the resultant intensity at 'P' is $\vec{E}-(E_{+q}+E_{-q})\cos\theta\,\hat{p}$, where $\hat{p}$ is unit vector in the direction of electric dipole moment.



$$\vec{E}=-\left(\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2+a^2}+\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2+a^2}\right)\frac{a}{\sqrt{r^2+a^2}}\hat{p} \qquad \left[\because \cos\theta=\frac{a}{\sqrt{r^2+a^2}}\right]=\frac{-1}{4\pi\varepsilon_0}\frac{2qa}{(r^2+a^2)^{3/2}}\hat{p}.$$

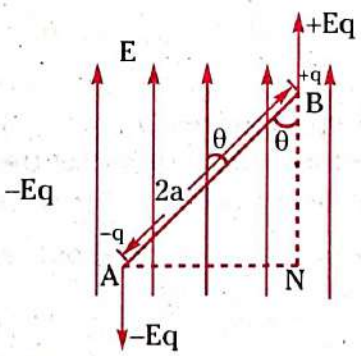
If $(r>>a)$, $\vec{E}=\frac{-1}{4\pi\varepsilon_0}\frac{2qa}{r^3}\hat{p}$, but $p=q\times 2a$

At a point on the equatorial plane, $\vec{E}=\frac{-1}{4\pi\varepsilon_0}\frac{P}{r^3}\hat{p}$. Therefore, the direction of electric field intensity on equatorial line of the dipole is opposite to dipole moment.

05. Derive an equation for the couple acting on a electric dipole in a uniform electric field.

May 14; TS May 18, Mar 19; AP May 16

Ans: Consider an electric dipole consisting of two charges +q and −q separated by a distance 2a. Let the dipole moment of electric dipole is 'p' and it is placed in a uniform electric field 'E' with an angle 'θ' as shown in figure.



The force acting on each charge is Eq. These two equal and unlike parallel forces form a couple. It will try to rotate the dipole parallel to the electric field. This is called moment of the couple.

Moment of the couple $\tau = F\times \perp^{lar}$ distance between the two forces $\Rightarrow \tau = F\times AN$

from ΔABN, we have $\sin\theta=\frac{AN}{AB}\Rightarrow AN=AB\sin\theta=2a\sin\theta$ $[\because AB=2a]$

$\tau=Eq\times 2a\sin\theta=PE\sin\theta$ $[\because P=q\times 2a]$. In vector form, $\vec{\tau}=\vec{P}\times\vec{E}$.

06. State Gauss's law in electrostatics and its importance. AP Mar 15, June 15; TS Mar 15, 18, May 17

Ans: **Gauss's law:** The total electric flux through any closed surface is equal to $\frac{1}{\varepsilon_0}$ times the net charge enclosed by the surface. Here, ε_0 is the permittivity of free space.

$\phi = \oint_s \vec{E} \cdot \overline{ds} = \frac{q}{\varepsilon_0}$. Here 'q' is the total charge enclosed by the surface 'S'.

Importance:

i) By using coulomb's law and the superposition principle, we can find electric field strength at a given point. But in case of more complex configurations of charge, the electric field can be more easily calculated by applying Gauss's law.

ii) Symmetric considerations in many problems make the application of Gauss's law much easier.

***** THE END*****

05 Electrostatic Potential & Capacitance

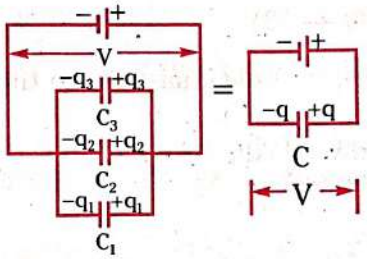
LAQ (0) - 0 × 8 = 0M
SAQ (1) - 1 × 4 = 4M
VSAQ(0) - 0 × 2 = 0M
Total Marks = 4M

LONG ANSWER QUESTIONS (8 MARKS)

01. Explain series and parallel combination of capacitors. Derive the formula for equivalent capacitance in each combination. **AP Mar & June15, May 16; TS Mar 15, 17, 19**

Ans: **Condensers in parallel:** If number of condensers are connected in such a way that the potential difference between the plates of every one of them is same, then the condensers are said to be connected in parallel.

Let three condensers of capacities C_1, C_2 and C_3 be connected in parallel as shown in figure. The potential



difference across each condenser is same and it is equal to V.

Let q_1, q_2 and q_3 be the charges on the plates of the condensers

of capacities C_1, C_2 and C_3 respectively.

$\therefore q = q_1 + q_2 + q_3$ —— (1); But $q_1 = C_1V$, $q_2 = C_2V$, $q_3 = C_3V$

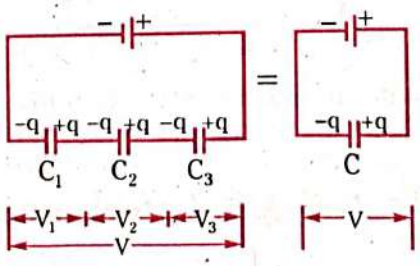
If 'C' is the equivalent capacity of the combination, then $C = \frac{q}{V} \Rightarrow q = CV$

$\therefore CV = C_1V + C_2V + C_3V$ (or) $C = C_1 + C_2 + C_3$ —— (2)

The equivalent capacity of the parallel combination is equal to the sum of their individual capacities.

Condensers in series: If number of condensers are connected in such way that the charge on the plates of every one of them is same, then the condensers are said to be connected in series.

Let three condensers of capacities C_1, C_2 and C_3 be connected in series as shown in figure. The charge on the plates of the condensers is same but the P.D across the condensers of capacities C_1, C_2, C_3 are V_1, V_2, V_3 respectively and 'V' be the potential difference across the combination of the condensers.



$\therefore V = V_1 + V_2 + V_3$ —— (1); But $V_1 = \frac{q}{C_1}$, $V_2 = \frac{q}{C_2}$, $V_3 = \frac{q}{C_3}$.

If 'C' is the equivalent capacity of the combination, then $V = \frac{q}{C}$

$$\therefore \frac{q}{C} = \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3} \Rightarrow \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \quad \text{—— (2)}$$

The reciprocal of the equivalent capacity is equal to the sum of reciprocal of the individual capacities.

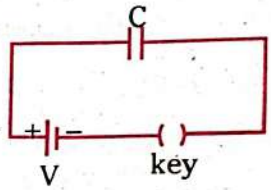
02. Derive expression for the energy stored in a capacitor. What is the energy stored when the space between the plates is filled with a dielectric
a) with charging battery disconnected b) with charging battery connected ?

AP Mar 05, 06, 07, 09; May 06

Ans: Let 'q' be the charge on the plates of a condenser and 'V' be the potential difference between plates. The work done dW in giving an additional charge dq to the condenser is given by,

$dW = Vdq$ —— (1)

But, capacity $C = \frac{q}{V} \Rightarrow V = \frac{q}{C}$ —— (2)



The total work done in giving the whole charge 'q' to the condenser is given by, $W = \int_0^q dW = \int_0^q Vdq$ [from(1)]

$$\Rightarrow W = \int_0^q \frac{q}{C} dq \quad \text{[from (2)]} \quad \left(\because \int x^n dx = \frac{x^{n+1}}{n+1} \Rightarrow \int q^1 dq = \frac{q^{1+1}}{1+1} = \frac{q^2}{2}\right)$$

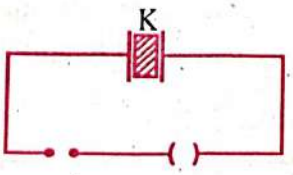
$$\Rightarrow W = \frac{q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}qV.$$

This work done in charging a condenser is stored as its potential energy,

$$U = \frac{q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}qV.$$

Effect of dielectric on energy stored in a capacitor: When dielectric slab is introduced between the plates of a capacitor, its capacity will increase. New capacity $C_1 = KC$ (where 'K' is dielectric constant of the slab introduced). As capacity changes energy stored in the capacitor will also change. This change is of two types:

Case-I: When the battery is disconnected from capacitor: When a capacitor is charged and disconnected from battery then the charge on the plates 'q' is constant. If a dielectric of constant 'K' is introduced between the plates, then energy stored.

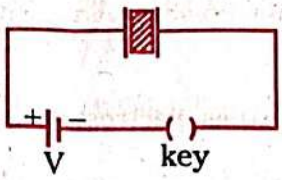


$U_1 = \frac{q^2}{2C_1}$, here, 'q' is constant and new capacity $C_1 = KC$.

$U_1 = \frac{q^2}{2KC} = \frac{U}{K}$ (where $U = \frac{q^2}{2C}$ is energy stored in capacitor without dielectric).

Energy stored in the capacitor decreases by K times.

Case-II: When the battery is present in the circuit: When the charging battery is present in the circuit, potential difference remains constant.



If a dielectric of constant 'K' is introduced, then $C_1 = KC$

and energy stored, $U_1 = \frac{1}{2}C_1V^2 = \frac{1}{2}KCV^2 = KU \left(\because U = \frac{1}{2}CV^2\right)$

$\therefore$ Energy stored in the capacitor increases by K times.

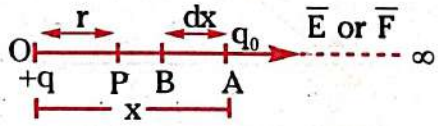
SHORT ANSWER QUESTIONS (4 MARKS)

03. Derive an expression for the electric potential due to point charge. AP Mar 16, 19, TS Mar 16

Ans: Electrostatic potential at any point in a region of electrostatic field is the work done in bringing a unit positive charge from infinity to that point against the electric field. $V = \frac{w}{q_0}$

Potential due to a point charge:

Consider a point charge 'q' at point 'O'. Charge is produced electric field around it.



Let q_0 be the test charge placed at A, the force acting on test charge is $F = \frac{1}{4\pi\varepsilon_0}\frac{qq_0}{x^2}$.

The test charge q_0 displaced towards +q from A to B through a displacement of dx against the electric field. The work done in moving the test charge is $dw = -Fdx$.

The total amount of work done in moving the test charge from ∞ to P,

$$\int dW = \int_{\infty}^{r} -Fdx \Rightarrow W = -\int_{\infty}^{r} \frac{1}{4\pi\varepsilon_0}\frac{qq_0}{x^2}dx \qquad \left[\because \int x^n dx = \frac{x^{n+1}}{n+1}\right]$$

$$\Rightarrow W = -\frac{qq_0}{4\pi\varepsilon_0}\int_{\infty}^{r}\frac{1}{x^2}dx = -\frac{qq_0}{4\pi\varepsilon_0}\left[-\frac{1}{x}\right]_{\infty}^{r} \Rightarrow W = \frac{1}{4\pi\varepsilon_0}\frac{qq_0}{r}.$$

$\therefore$ The potential at point 'P' is $V = \frac{W}{q_0} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$.

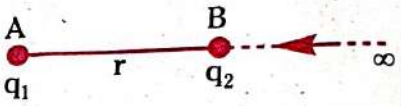
04. Derive the expression for the electrostatic potential energy of a system of two point charges and find its relation with electric potential of a charge.

Ans: **Statement:** The amount of workdone to arrange the charges at a particular separation is stored in the system as potential energy is called electrostatic potential energy of system of charges.

Let two point charges q_1 and q_2 are separated by distance in space. An electric field will develop around the charge q_1. The potential at B due to q_0 at a distance 'r' is $V_B = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r}$

To bring a charge q_2 from infinity to the point B, some work must be done.

Work done, $W = q_2V_B = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$.



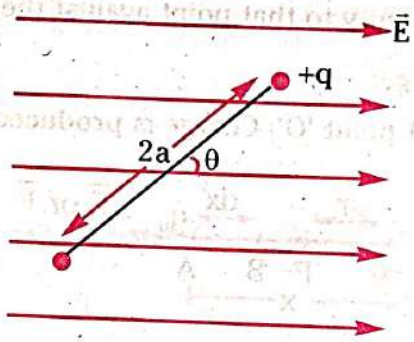
Thus amount of work done is stored as electrostatic potential energy (U) of a system of two charged particles. $\therefore U = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$.

05. Derive an expression for the potential energy of an electric dipole placed in a uniform electric field.

Ans: Consider a dipole with charges $q_1 = +q$ and $q_2 = -q$ placed in a uniform electric field E as shown in figure.

The dipole experiences no net force, but experiences a torque τ given by $\bar{\tau} = \bar{P} \times \bar{E}$

$\Rightarrow |\bar{\tau}| = P.E\sin\theta$.



Suppose an external toque τ_{ext} is applied such that it just neutralises this torque and rotates it in the plane of paper from angle θ_0 to angle θ_1 without angular acceleration.

The amount of work done $W = \int_{\theta_0}^{\theta_1} \tau_{ext} d\theta = \int_{\theta_0}^{\theta_1} P.E\sin\theta d\theta = P.E(-\cos\theta)_{\theta_0}^{\theta_1} = P.E(\cos\theta_0 - \cos\theta_1)$

This work is stored as potential energy in the system.

We can then associate potential energy $U(\theta)$ with an inclination θ of the dipole

Work done in rotating from $\theta_0 = \frac{\pi}{2}$ to $\theta_1 = 0$, $U_{(\theta)} = P.E\left[\cos\frac{\pi}{2} - \cos\theta\right] = -PE\cos\theta = -\bar{P}.\bar{E}$.

06. Derive an expression for the capacitance of a parallel plate capacitor.

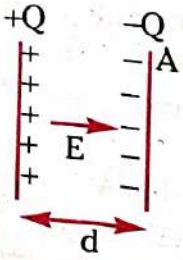
AP Mar 16, 18, 20, May 16, 17; TS Mar 18, 20, May 16, 18

Ans: A parallel plate capacitor consists of two large plane parallel conducting plates separated by a small distance 'd'.

Let 'A' be the area of each plate and 'd' be the distance between the plates. The two plates have charges +Q and –Q.

The surface charge density of positive plate is $\sigma = \frac{Q}{A}$

Eelctric field between plates is $E = \frac{V}{d} = \frac{\sigma}{\varepsilon_0} \Rightarrow \frac{V}{d} = \frac{Q}{A\varepsilon_0}$



'V' is potential difference between two plates $\frac{A\varepsilon_0}{d} = \frac{Q}{V}$ —— (1)

$\therefore$ The capacitance of the parallel plate capacitor $C = \frac{Q}{V}$ —— (2)

from (1) & (2), $C = \frac{A\varepsilon_0}{d}$

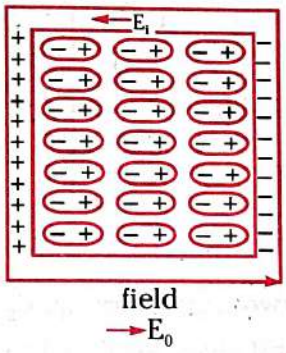
If the medium between the plates filled with a medium of dielectric constant 'K', then

$C_m = \frac{KA\varepsilon_0}{d} = KC$.

07. Explain behaviour of dielectrics in an electric field. **AP Mar 19**

Ans: In polar dielectric substances, charge is not distributed symmetrically i.e., centres of positive and negative charges do not coincide even in the absence of electric field.

In non polar dielectric substances charge is distributed symmetrically i.e., centres of positive and negative charges coincide even in the absence of electric field. When non-polar dielectric substances are placed in an external field E_0, in each molecule the centre of positive charge will be displaced in the direction of the field, the centre of negative charge in the opposite direction. Each molecule is said to get polarised.



As the molecules are polarized in an electric field, surface charge will develop on each molecule and these induced charges are in opposite direction to the applied field. These induced charges will develop electric field E_i in opposite direction. Due to charge polarization, intensity of electric field in a dielectric reduces.

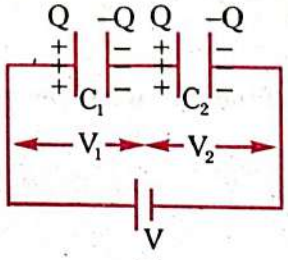
The value of actual intensity $E = \frac{E_0}{K}$ so, capacity increases by K times.

08. Derive the formula for equivalent capacitance when the capacitors are connected in series. **AP 15, TS 15, 19, 22**

Ans: **Equivalent Capacitance of capacitors in Series:**

1) Suppose that two capacitors of capacitance C_1, C_2 are connected in series to a potential difference V.
2) In series combination of capacitors, same charge Q is stored on the plates of two capacitors.
3) Let V_1, V_2 be the potential drops formed on the capacitors C_1, C_2 respectively.
4) In series combination of capacitors, the total potential drop is equal to sum of potential drops on the capacitors.

$\therefore V = V_1 + V_2$



But $V_1 = \frac{Q}{C_1}$ and $V_2 = \frac{Q}{C_2}$

$\therefore V = \frac{Q}{C_1} + \frac{Q}{C_2} \Rightarrow V = Q\left(\frac{1}{C_1} + \frac{1}{C_2}\right) \Rightarrow \frac{V}{Q} = \frac{1}{C_1} + \frac{1}{C_2}$ ——— (1)

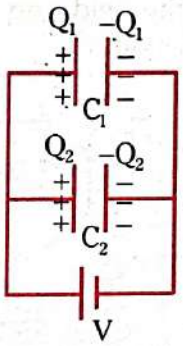
Then effective capacitance of the combination is $\frac{1}{C} = \frac{V}{Q}$ ——— (2)

From (1) & (2), we bet $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$.

09. Derive the formula for equivalent capacitance when the capacitors are connected in parallel.
AP 16, TS 17

Ans: Equivalent Capacitance of capacitors in Parallel:

1) Suppose that two capacitors of capacitance C_1, C_2 are connected in parallel to a potential difference V.
2) In parallel combination of capacitors, same PD of V remains on all the capacitors.



3) Let Q_1, Q_2 be the charges on two capacitors C_1, C_2.
4) In parallel combination, the total charge is equal to sum of charges stored in capacitors. $\therefore Q = Q_1 + Q_2$
5) But $Q_1 = C_1V$ and $Q_2 = C_2V$. $\therefore Q_1 = C_1V + C_2V$
6) Here the capacitors act as an equivalent capacitor with charge Q, potential drop V and equivalent capacitance C. So, $Q = CV$.

$\therefore CV = C_1V + C_2V = (C_1 + C_2)V \Rightarrow C = C_1 + C_2$.

PROBLEMS

10. Three capacitors each of capacitance 9 pF are connected in series
a) What is the total capacitance of the combination ?
b) What is the potential difference across each capacitor if the combination is connected to a 120 V supply ?
May 14; EXERCISE PROBLEM

Sol: a) Effective capacitance when capacitors are connected in series is given by

$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} = \frac{1}{C} + \frac{1}{C} + \frac{1}{C} = \frac{3}{C} \Rightarrow C_S = \frac{C}{3} = \frac{9}{3} = 3\text{ pF}$.

b) As capacitors are identical, potential on each capacitor $V = \frac{V}{3}$, where 'V' is applied potential

$= \frac{120}{3} = 40\text{ V}$.

11. Three capacitors of capacitances 2 pF, 3 pF and 4 pF are connected in parallel.

a) What is the total capacitance of the combination ?

b) Determine the charge on each capacitor if the combination is connected to a 100 V supply.

AP Mar 17; EXERCISE PROBLEM

Sol: When capacitors are connected in parallel, effective capacitance is given by $C_P = C_1 + C_2 + C_3 = 9\,pF$.

$q_1 = C_1V = 2\times10^{-12}\times100 = 200\times10^{-12}C$, $q_2 = C_2V = 3\times10^{-12}\times100C = 300\times10^{-12}C$,

$q_3 = C_3V = 4\times10^{-12}\times100C = 400\times10^{-12}C$.

12. A 12 pF capacitor is connected to a 50 V battery. How much electrostatic energy is stored in the capacitor ?

EXERCISE PROBLEM

Sol: Electrostatic energy stored in the capacitor is $U = \frac{1}{2}CV^2 = \frac{1}{2}12\times10^{-12}\times50\times50 = 1.5\times10^{-8}J$.

***** THE END*****

06 Current Electricity

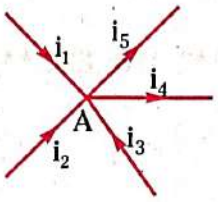
LAQ (I) - 1 × 8 = 8M
SAQ (II) - 0 × 4 = 0M
VSAQ(III) - 0 × 2 = 0M
Total Marks = 8M

LONG ANSWER QUESTIONS (8 MARKS)

01. State Kirchhoff's laws for electrical network. Using these laws, deduce the condition for balancing in a Wheatstone bridge.

May 14; AP Mar 14, 18, 19, 20, May 16; TS June 15, Mar 16, 18, May 18

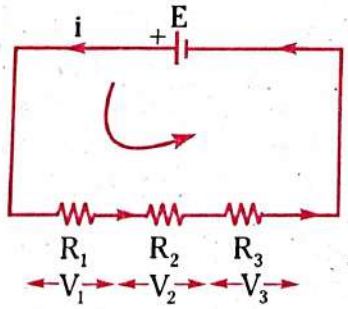
Ans: **a) Kirchhoff's current law (or) First law:** The sum of current flowing into a junction is equal to sum of currents flowing out of same junction. (or) The algebraic sum of all the currents meeting at any junction is zero.



From kirchhoff's current law, $i_1 + i_2 + i_3 = i_4 + i_5 \Rightarrow i_1 + i_2 + i_3 - i_4 - i_5 = 0$.

This is based on law of conservation of charge.

b) Kirchhoff's voltage law: In any closed circuit, the algebraic sum of the potential differences is equal to zero. This law is based on law of conservation of energy. $\Sigma V = 0$



Sign convention:

i) When we move across resistor in the direction of current, the potential drop across the resistor is taken as $-iR$.

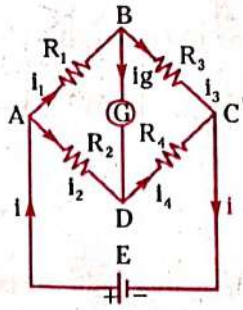
ii) When we move across resistor in the opposite direction of current, the potential drop across the resistor is taken as $+iR$.

iii) If we move from negative terminal to positive terminal of a cell, then its emf is taken as positive.

iv) If we move from positive terminal to negative terminal of a cell, then its emf is taken as negative.

From the above figure, $E - iR_1 - iR_2 - iR_3 = 0 \Rightarrow E = iR_1 + iR_2 + iR_3 \Rightarrow i = \dfrac{E}{R_1 + R_2 + R_3}$.

Wheatstone's Bridge: Wheatstone bridge consists of four resistances R_1, R_2, R_3 and R_4 connected as shown in the figure to four junctions A, B, C and D. Between the junction A and C, a battery of emf 'E' is connected. Between the junctions B and D, a galvanometer 'G' is connected.



Applying Kirchhoff's first law at the junction 'B', $i_1 = i_g + i_3$ —— (1)

at the junction 'D', $i_2 + i_g = i_4$ —— (2)

Applying Kirchhoff's second law for the closed mesh ABDA, going in the clock wise direction

$-i_1R_1 - i_gG + i_2R_2 = 0$ —— (3)

And for BCDB, again going in the clockwise direction

$-i_3R_3 + i_gG + i_4R_4 = 0$ —— (4)

When no current passes through the galvanometer, $i_g = 0$, the bridge is said to be balanced.

Using $i_g = 0$ in above equations, $i_1 = i_3$ —— (5), $i_2 = i_4$ —— (6),

$i_1R_1 = i_2R_2$ —— (7), $i_3R_3 = i_4R_4$ —— (8)

Dividing equation (7) and (8), $\frac{i_1R_1}{i_3R_3} = \frac{i_2R_2}{i_4R_4} \Rightarrow \frac{R_1}{R_3} = \frac{R_2}{R_4}$. This is the principle of Wheatstone's bridge.

02. State the working principle of potentiometer. Explain with the help of circuit diagram how the emf of two primary cells is compared by using the potentiometer.

AP June 15, Mar 16, 17, May 17; TS May 16, Mar 19

Ans: **Working principle of potentiometer:** It works on the principle that the potential difference across any part of a uniform wire is directly proportional to the length of that portion when a constant current flows through the wire.

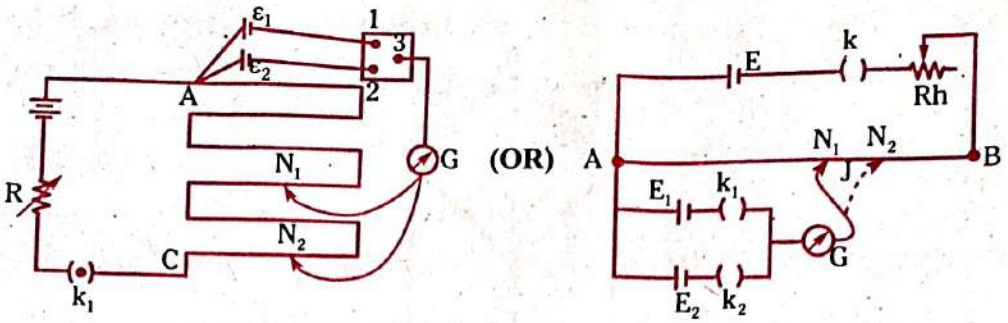
Let 'V' be the potential difference across the wire of length 'ℓ' resistance 'R' and uniform area of cross-section 'A'. If 'I' be the current following through the wire, then according to ohms law $V = IR$.

But, $R = \frac{\ell}{A}$, where ρ = Resistivity of the wire

$V = I \cdot \rho\frac{\ell}{A} = \left(\frac{I\rho}{A}\right)\ell$, but, $\frac{I\rho}{A} = \phi$. $\therefore V = \phi\ell$ (or) $V \propto \ell$ provided A, ρ & I are constants.

Comparison of emf's of two cells using potentiometer: Let E_1 and E_2 be the emf of the two cells under comparison. The primary circuit consists of a cell of emf 'E', internal resistance 'r' connected in series to a key k_1 and rheostat.

In the secondary circuit, two cells whose emf's E_1 and E_2 are to be compared are connected. While making the connections, the positive terminals of the cells are to be connected to the end of potentiometer wire, where the positive terminal of the cell in the primary circuit is connected.



First, the key is connected so that the galvanometer is connected to E_1. The position of jockey is adjusted on the potentiometer wire and balance point is obtained at $\ell_1(AN_1)$

Then $E_1 = \phi\ell_1$ —— (1), where 'ϕ' is the potential drop per unit length.

Now, key is connected so that the galvanometer is connected to E_2.

The position of jockey is adjusted on the potentiometer wire and balance point is obtained at $\ell_2(AN_2)$. $\therefore E_2 = \phi\ell_2$ —— (2)

Divide (1) and (2), $\frac{E_1}{E_2} = \frac{\ell_1}{\ell_2}$.

03. State the working principle of potentiometer and explain with the help of circuit diagram. How the potentiometer is used to determine the internal resistance of the given primary cell ?

AP Mar 15, May 18; TS Mar 15, 17, 20, May 17

Ans: **Working principle of potentiometer:** It works on the principle that the potential difference across any part of a uniform wire is directly proportional to the length of that portion when a constant current flows through the wire.

Let 'V' be the potential difference across the wire of length 'ℓ' resistance 'R' and uniform area of cross-section 'A'.

If 'I' be the current following through the wire, then according to ohm's law, $V = IR$

But $R = \rho\frac{\ell}{A}$, where ρ = Resistivity of the wire.

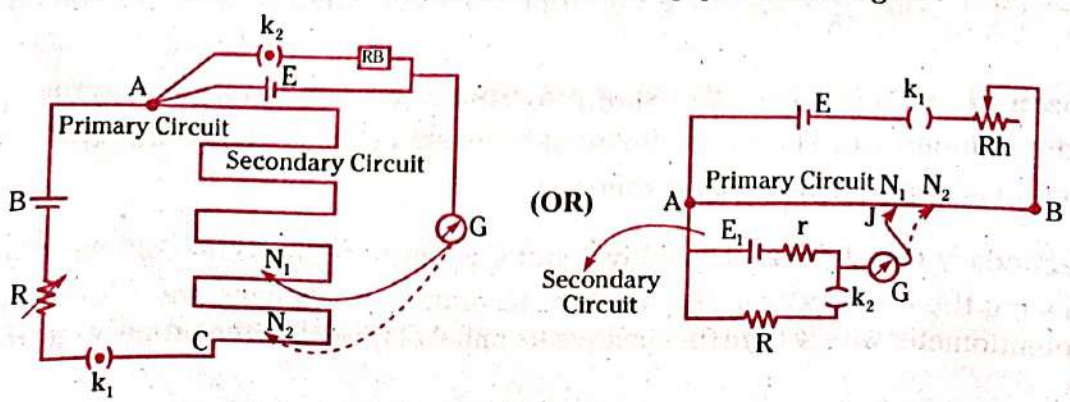
$V = I\cdot\rho\frac{\ell}{A} = \left(\frac{I\rho}{A}\right)\ell$, but $\frac{I\rho}{A} = \phi$. $\therefore V = \phi\ell$ (or) $V \propto \ell$ provided A, ρ & I are constants.

Determination of internal resistance of a cell using potentiometer: The arrangement for measuring the internal resistance 'r' of a cell using potentiometer is shown in the diagram.

The primary circuit consists of a cell of emf 'B' with some internal resistance connected in series with a key K_1 and rheostat 'R'.

A cell of emf 'E' whose internal resistance 'r' is to be determined is connected across a resistance box to a key K_2 as shown in figure. With key K_2, open balance point is obtained at length $\ell_1(AN_1)$.

Then $E = \phi\ell_1$ —— (1), where 'ϕ' is the potential drop per unit length.



When key K_2 is closed, the cell sends a current to the resistance box. If 'V' is the terminal potential difference of the cell and balance point is obtained at length $\ell_2(AN_2)$.

Then $V = \phi\ell_2$ —— (2)

So, we have from (1) and (2), $\frac{E}{V} = \frac{\ell_1}{\ell_2}$ —— (3)

But, $E = I(r+R)$ and $V = IR$ this gives $\frac{E}{V} = \frac{r+R}{R}$ —— (4)

From (3) and (4), $\frac{r+R}{R} = \frac{\ell_1}{\ell_2} \Rightarrow \frac{r}{R}+1 = \frac{\ell_1}{\ell_2} \Rightarrow \frac{r}{R}+1 = \frac{\ell_1}{\ell_2} \Rightarrow \frac{r}{R} = \frac{\ell_1}{\ell_2}-1 = \frac{\ell_1-\ell_2}{\ell_2} \Rightarrow r = R\left(\frac{\ell_1-\ell_2}{\ell_2}\right)$.

04. Three identical resistors are connected in parallel and the total resistance of the circuit is R / 3. Fxind the value of each resistance. **AP May 14**

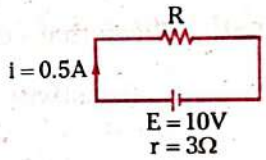
Ans: Three equal resistors each of resistance is 'x' connected in parallel, the effective resistance is $\frac{R}{3}$, then the value of resistance is $\frac{1}{R_{effective}} = \frac{1}{x}+\frac{1}{x}+\frac{1}{x} \Rightarrow \frac{1}{R/3} = \frac{3}{x} \Rightarrow \frac{3}{R} = \frac{3}{x} \Rightarrow \frac{1}{R} = \frac{1}{x} \Rightarrow R = x$.

05. A battery of emf 10 V and internal resistance 3 Ω, is connected to a resistor 'R'

i) If the current in the circuit is 0.5 A, then calculate the value of 'R' ?

ii) What is the terminal voltage of the battery when the circuit is closed. **TS Mar 15**

Ans: i) $i = \frac{E_{tot}}{R_{tot}} = \frac{E}{R+r} \Rightarrow 0.5 = \frac{10}{R+3} \Rightarrow R = 17\Omega$



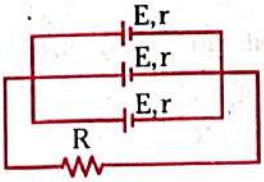
ii) Terminal voltage $V = E - ir$ $(\because E = V + ir)$

$\Rightarrow V = 10 - 0.5(3) = 8.5\ V$ (or) $V = iR = 0.5 \times 17 = 8.5V$.

06. 'm' cells each of emf 'E' and internal resistance 'r' are connected in parallel. What is the total emf and internal resistance ? Under what conditions the current drawn from mixed grouping of cells is maximum ?

Ans: If all positive terminals of cells are joined together, then it is said to be parallel combination.

Consider 'm' identical cells such as $E_1, E_2, E_3 .... E_m$ each of emf 'E' and internal resistance 'r' connected in parallel to an external resistance 'R'.



Effective resistance, $\frac{1}{r_{eff}} = \frac{1}{r_1}+\frac{1}{r_2}+\frac{1}{r_3}+....+\frac{1}{r_m} \Rightarrow r_{eff} = \frac{r}{m} \Rightarrow \frac{1}{r_{eff}} = \frac{m}{r} \Rightarrow r_{eff} = \frac{r}{m}$

Total resistance, $R + r_{eff} = R + \frac{r}{m}$; Current, $I = \frac{E}{R+(r/m)} = \frac{mE}{mR+r}$

Result: If total internal resistance is equal to external resistance, we get maximum current.

PROBLEMS

07. How many electrons flow through a wire when 1A current passes for one milli second ?

AP Mar 10

Sol: $i = 1\,A,\ t = 1\,ms = 1\times10^{-3}\ sec,\ n = ?,\ e = 1.6\times10^{-19}\ C$

$$i = \frac{q}{t} = \frac{ne}{t} \Rightarrow 1 = \frac{n\times1.6\times10^{-19}}{10^{-3}} \Rightarrow n = \frac{1}{1.6\times10^{-16}} = 6.25\times10^{15}\ \text{electrons}.$$

08. A wire carries a current of 1A, then a) How much charge flows through the wire in 5 minutes. b) How much electrons will cross over a particular point in the conductor during this period.

AP May 12

Sol: $i = iA,\ q = ?,\ t = 5\,min = 5\times60 = 300\ sec,\ n = ?$

a) $i = \frac{q}{t} \Rightarrow q = it \Rightarrow q = 1\times300 = 300\,C.$

b) $i = \frac{q}{t} \Rightarrow i = \frac{ne}{t} \Rightarrow 1 = \frac{n\times1.6\times10^{-19}}{300}$

$$\Rightarrow n = \frac{300}{1.6\times10^{-19}} = 187.5\times10^{19}\ \text{electrons}.$$

09. Find the resistivity of a conductor which carries a current of density of $2.5\times10^{6}\,Am^{-2}$ when an electric field of 15 Vm^{-1} is applied across it.

AP Mar 15; SOLVED PROBLEM

Sol: Given that current density $(J) = 2.5\times10^{6}\,Am^{-2}$, applied electric field $(E) = 15\ Vm^{-1}$

$\therefore$ Resistivity of conductor $\rho = ?$

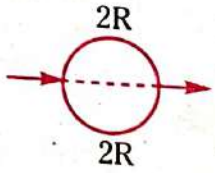
$\therefore$ We know that, $E = J\rho \Rightarrow \rho = \frac{E}{J} = \frac{15}{2.5\times10^{6}} \Rightarrow \rho = \frac{150}{25}\times10^{-6} = \frac{30}{5}\times10^{-6} = 6\times10^{-6}\,\Omega m.$

10. A wire of resistance 4R is bent in the form of a circle. What is the effective resistance between the ends of the diameter ?

TS Mar 16; SOLVED PROBLEM

Sol: Given the resistance of the straight wire $R_1 = 4R$. When the wire is bent in the form of circle we assume the wire is divided into two equal parts above and below the diameter.

Hence, resistance of each part becomes $\frac{R_1}{2} = \frac{4R}{2} = 2R.$



Now assume these two parts [resistance] are connected in parallel, then

$$R_p = \frac{2R\times2R}{2R+2R} = \frac{4R^2}{4R} = R \left[\because R_p = \frac{R_1R_2}{R_1+R_2}\right].$$

11. a) Three resistors 2 Ω, 4 Ω and 5 Ω are combined in parallel. What is the total resistance of the combination ?

b) If the combination is connected to a battery of emf 20V and negligible internal resistance, determine the current through each resistor and the total current drawn from the battery.

TS Mar 18; EXERCISE PROBLEM

Sol: a) $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{2} + \frac{1}{4} + \frac{1}{5} = \frac{19}{20} \Rightarrow R_P = \frac{20}{19}\Omega.$

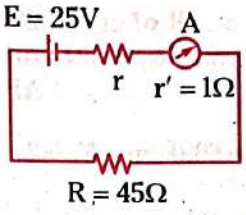
b) Currents drawn through different resistors are

$$I_1 = \frac{E}{R_1} = \frac{20}{2} = 10A,\ I_2 = \frac{E}{R_2} = \frac{20}{4} = 5A,\ I_3 = \frac{E}{R_3} = \frac{20}{5} = 4A.$$

Total current drawn from the battery $I = I_1 + I_2 + I_3 = 10+5+4 = 19A$.

12. A battery of emf 2.5 V and internal resistance r is connected in series with a resistor of 45 ohm through an ammeter of resistance 1 ohm. The ammeter reads a current of 50 mA. Draw the circuit diagram and calculate the value of 'r' ? **TS Mar 17; SOLVED PROBLEM**

Sol: Given that emf of cell $(E) = 2.5$ V, Internal resistance of cell $r = ?$,



Ammeter resistance $(r') = 1\Omega$, External resistance $(R) = 45\Omega$,

Current $(i) = 50\,mA = 5\times10^{-2}A$

$$\therefore i = \frac{E}{R+r+r'} \Rightarrow R+r+r' = \frac{E}{i} \Rightarrow 45+1+r = \frac{2.5}{5\times10^{-2}} \Rightarrow 46+r = 50 \Rightarrow r = 4\Omega.$$

13. The four resistors 20 Ω, 40 Ω, (20 + x)Ω, 80 Ω respectively form a Wheatstone bridge. Find the value of 'x' ? **AP Mar 20; SOLVED PROBLEM**

Sol: From Wheatstone bridge balancing condition $\frac{P}{Q} = \frac{R}{S} \Rightarrow \frac{20}{40} = \frac{(20+x)}{80} \Rightarrow 40 = 20+x.\ \therefore x = 20\Omega.$

14. Two unknown resistance P an Q are connected in the left and right gaps of a meter bridge and balancing point is obtained at 60 cm from the left. When a 20 Ω resistance is connected in parallel to 'P' the balance point is at 5 Ω calculate 'P' and 'Q' ? **AP May 09**

Sol: $X = P,\ R = Q,\ \ell_1 = 60$ cm, $\ell_2 = 40$ cm

$$\frac{X}{R} = \frac{\ell_1}{\ell_2} \Rightarrow \frac{P}{Q} = \frac{60}{40} = \frac{3}{2}$$

When 20 Ω resistance is connected to 'P', $\ell_1' = 50$ cm, $\ell_2' = 50$ cm

$$\frac{P\times20}{(P+20)Q} = \frac{\ell_1'}{\ell_2'} \Rightarrow \frac{3}{2}\times\frac{20}{P+20} = \frac{50}{50} \Rightarrow P+20 = 30 \Rightarrow P = 10\,\Omega$$

$$\therefore \frac{P}{Q} = \frac{3}{2} \Rightarrow \frac{10}{Q} = \frac{3}{2} \Rightarrow Q = \frac{20}{3} = 6.67\,\Omega.$$

15. Find the balance length in a metre bridge, if the resistance in the left and right gaps are in the ratio of 2 : 3. **AP Mar 07**

Sol: $$\frac{P}{Q} = \frac{\ell_1}{100-\ell_1} \Rightarrow \frac{2}{3} = \frac{\ell_1}{100-\ell_1} \Rightarrow 2(100-\ell_1) = 3\ell_1 \Rightarrow 200-2\ell_1 = 3\ell_1 \Rightarrow 200 = 5\ell_1 \Rightarrow \ell_1 = 40\text{ cm}.$$

The balancing point is obtained at 40 cm from the left.

16. A potentiometer wire is 5 m long and a potential difference of 6V is maintained between its ends. Find the emf of a cell which balances against a length of 180 cm of the potentiometer wire.

TS May 16; AP June 15, Mar 16, 17; SOLVED PROBLEM

Sol: Length of potentiometer wire $L = 5m$.

Potential difference across its ends $V = 6V$.

Balancing length of wire $\ell = 180\,cm = 1.8\,m$.

$\therefore$ Emf of the cell $E = \frac{V}{L}\ell = \frac{6}{5} \times 1.8 = 2.16\,V$.

17. In a potentiometer arrangement, a cell of emf 1.25 V gives a balance point 35.0 cm length of the wire. If the cell is replaced by another cell and the balance point shifts to 63.0 cm, what is the emf of the second cell ?

AP Mar 15; TS Mar 20; EXERCISE PROBLEM

Sol: Here, $E_1 = 1.25\,V$, $\ell_1 = 35.0\,cm$, $\ell_2 = 63.0\,cm$, $E_2 = ?$

As $\frac{E_2}{E_1} = \frac{\ell_2}{\ell_1} \Rightarrow E_2 = \frac{\ell_2}{\ell_1} \times E_1 = \frac{63 \times 1.25}{35} = 2.25\,V$.

***** THE END*****

07 Moving Charges and Magnetism

LAQ (0) - 0 × 8 = 0M
SAQ (1) - 1 × 4 = 4M
VSAQ(1) - 1 × 2 = 2M
Total Marks = 6M

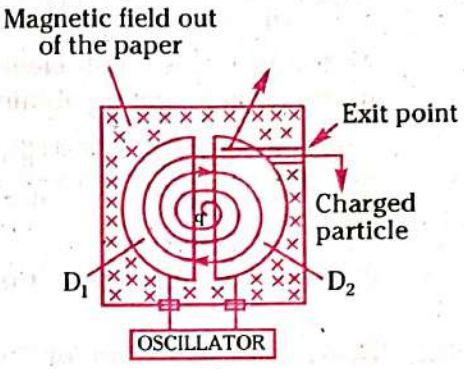
SHORT ANSWER QUESTIONS (4 MARKS)

01. What are the basic components of cyclotron ? Mention its uses ? **AP May 16**

Ans: Cyclotron is a device used to accelerate positively charged particles like protons, α - particles.

Cyclotron mainly consists of

1) Two hollow D-shaped metallic chambers D_1 and D_2
2) High frequency oscillator
3) Strong electromagnet
4) Vacuum chamber



Uses of cyclotron:

1) It is used for producing radioactive material for medical purposes. i.e., diagnostics and treatment of chronic diseases.
2) It is used to improve the quality of solids by adding ions.
3) It is used to synthesis fresh substances.
4) It is used to bombard the atoms with highly accelerated particles to study the nuclear reactions.

02. State and explain Biot-Savart law. **May 14; AP Mar 16, 17, 18; TS Mar 16, 17, 20**

Ans: **Statement:** The magnitude of magnetic field induction due to small element of current carrying conductor is directly proportional to the strength of the current, length of the element, sine of the angle between position vector and the element and inversely proportional to the square of the distance of the point from the element.

Explanation: Consider a finite conductor QR carrying current 'I'. Consider a small element of the conductor of length $\overrightarrow{d\ell}$. Let dB is the magnetic induction due to this small element at a point p which is at a distance r from the element. Let θ be the angle between $\overrightarrow{d\ell}$ and the position vector $\vec{r}$.

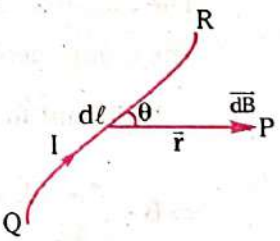
According to Biot and Savart's law,

i) The magnitude of magnetic field dB is proportional to the current $dB \propto i$,

ii) Magnetic field dB is proportional to length of current carrying element $dB \propto d\ell$.

iii) Since of the angle between the current carrying element and the line joining the midpoint of the element and the given point $dB \propto \sin\theta$.

iv) Magnetic field dB is inversely proportional to the square of the distance 'r' of given point from the current carrying element $dB \propto \frac{1}{r^2}$



$$dB \propto \frac{id\ell\sin\theta}{r^2} \Rightarrow dB = k\frac{id\ell\sin\theta}{r^2} \quad \left[\because k = \frac{\mu_0}{4\pi}\right].$$

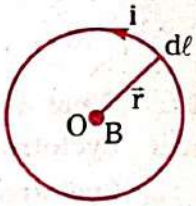
If the conductor is in vacuum (or) air, then $dB = \frac{\mu_0}{4\pi}\frac{id\ell\sin\theta}{r^2}$ where μ_0 = permeability of free space and $\frac{\mu_0}{4\pi} = 10^{-7}\ Wb\ m^{-1}A^{-1}$. In vector form, $\overrightarrow{dB} = \frac{\mu_0 i}{4\pi}\frac{(\overrightarrow{d\ell}\times\vec{r})}{r^3}$.

03. Derive an expression for the magnetic induction at the centre of a current carrying circular coil using Biot-Savart law.

Ans: Consider a circular coil of radius 'r' and carrying a current 'i'. Consider a small length element '$d\ell$' of the coil. Let 'O' is the centre of the coil.

By using Biot-Savart's law, the magnetic induction at centre 'O' due to the small element is,

$$dB = \frac{\mu_0}{4\pi}\frac{id\ell\sin\theta}{r^2}.$$



Here, angle between $\overline{d\ell}$ and $\bar{r}$ is 90° (i.e., $\theta = 90°$)

$$\therefore dB = \frac{\mu_0}{4\pi}\frac{id\ell}{r^2} \quad \text{——— (1)}$$

As the field due to all elements of the circular loop have the same direction. The resultant magnetic field can be obtained by integrating equation (1).

$$B = \int dB = \int \frac{\mu_0}{4\pi}\frac{id\ell}{r^2} \Rightarrow B = \frac{\mu_0 i}{4\pi r^2}\int d\ell \quad (\because \int d\ell = 2\pi r) \Rightarrow B = \frac{\mu_0 i}{4\pi r^2}\times 2\pi r = \frac{\mu_0 i}{2r}.$$

If the circular coil has 'n' turns, $B = \frac{\mu_0 ni}{2r}$.

04. Derive an expression for the magnetic induction at a point on the axis of a current carrying circular coil using Biot-Savart law. **TS Mar 16**

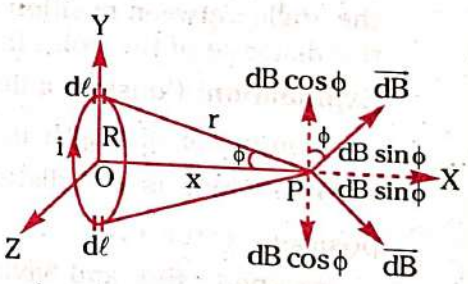
Ans: **Magnetic field at a point on the axis of a circular coil carrying electric current:**

Consider a circular coil of radius 'R' carrying a current 'i'. Let 'P' is a point on the axis at a distance 'x' from the centre 'O'. Let 'r' be the distance of small element ($d\ell$) from 'P'.

From Biot-Savart's law, the magnetic field induction at 'P'

due to this element is $dB = \frac{\mu_0}{4\pi}\frac{id\ell\sin\theta}{r^2}$

$= \frac{\mu_0}{4\pi}\frac{id\ell}{r^2}$ ——— (1) ($\because \theta = 90°$ Angle between $\overline{d\ell}$ and $\bar{r}$)



$\overline{dB}$ can be resolved into two components $dB\cos\phi$ and $dB\sin\phi$, if we consider another element of same length ($d\ell$) diametrically opposite to first element.

The magnetic field induction at 'P' due to this also resolved into $dB\cos\phi$ and $dB\sin\phi$.

The components along the axis will add up and perpendicular to the axis will cancel.

$\therefore$ Resultant magnetic induction at 'P' is $B = \int dB\sin\phi$ ——— (2)

$$\Rightarrow B = \int \frac{\mu_0}{4\pi}\frac{id\ell\sin\phi}{r^2} = \frac{\mu_0 i}{4\pi r^2}\int d\ell\sin\phi \qquad \left(\because \sin\phi = \frac{R}{r}\right)$$

$$= \frac{\mu_0 i}{4\pi r^2}\times 2\pi R\times\frac{R}{r} \qquad (\because \int d\ell = 2\pi r) \Rightarrow B = \frac{\mu_0 iR^2}{2r^3} \quad \text{——— (3)}$$

From figure $r = \sqrt{R^2 + x^2}$, $B = \frac{\mu_0 iR^2}{2(R^2+x^2)^{3/2}}$ ——— (4)

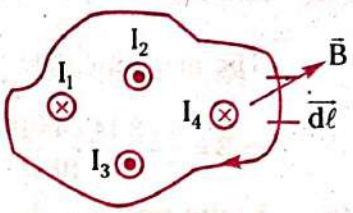
If the coil contains N turns, $B = \frac{\mu_0 NiR^2}{2(R^2+x^2)^{3/2}}$ ——— (5).

05. State and explain Ampere's law. **AP Mar 20; TS Mar 18**

Ans: **Ampere's law or Ampere's circuit law:**

Statement: The line integral of the intensity of magnetic induction field around any closed path is equal to μ_0 times the net current enclosed in it. $\oint \vec{B}\cdot\vec{d\ell} = \mu_0 I$ —— (1)

Explanation: Consider a closed path of any shape. We have to take a small length element $\vec{d\ell}$ on the closed path. Let $\vec{B}$ be the resultant magnetic field at the position of $\vec{d\ell}$. The scalar product of $\vec{B}$ and $\vec{d\ell}$ is $\vec{B}\cdot\vec{d\ell}$. Integrating $\vec{B}\cdot\vec{d\ell}$ by varying $\vec{d\ell}$ on the closed path we get the line integral of $\vec{B}$ around the closed path. It is denoted by the symbol $\oint \vec{B}\cdot\vec{d\ell}$.



By Ampere's law, $\oint B\cdot d\ell = \mu_0 I$, where 'I' is the net current enclosed by the closed path.

The currents I_1, I_4 which are normally into the plane of the paper are taken as positive and the currents I_2, I_3 which are normally outwards are taken as negative. Thus $I = I_1 - I_2 - I_3 + I_4$.

06. Find the magnetic induction due to a long current carrying conductor ?

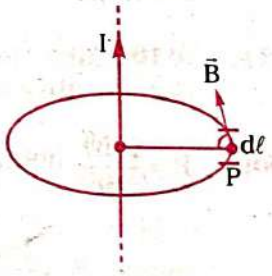
Ans: Consider a long straight conductor carrying a current 'i'. Let 'P' be a point at a distance 'r' from the conductor. Let 'r' be the radius of the circle passing through point 'P'.

Magnetic induction is same at all points on the circle. Consider a small element of length $d\ell$.

Now, $\oint \vec{B}\cdot\vec{d\ell} = \oint B d\ell \cos\theta = B\oint d\ell$ [$\because$ Angle between B and $d\ell$ is zero i.e., $\theta = 0°$]

[$\because \oint d\ell = 2\pi r$ = circumference of the circle]

$\Rightarrow \oint \vec{B}\cdot\vec{d\ell} = B(2\pi r)$ —— (1)



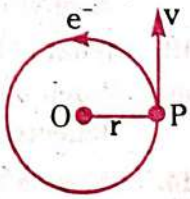
According to Ampere's law, $\oint \vec{B}\cdot\vec{d\ell} = \mu_0 i$ —— (2)

From equation (1) and (2), $B(2\pi r) = \mu_0 i \Rightarrow B = \dfrac{\mu_0 i}{2\pi r}$.

07. Derive an expression for the magnetic dipole moment of a revolving electron. **AP Mar 16**

Ans: Consider an electron revolving in a circular orbit of radius r with speed 'v' and frequency 'f'. Consider a point 'P' on the circle. If the electron crosses this point P on the circle in every revolution, then distance travelled by electron to complete one revolution $= 2\pi r$.

No. of revolutions in one second $(f) = \dfrac{v}{2\pi r}$.



The electric current $(i) = \dfrac{\text{charge of the electron}}{\text{time taken for one revolution}}$

$= \text{charge} \times \text{frequency} \Rightarrow i = e \times \dfrac{v}{2\pi r}$.

$\therefore$ Magnetic dipole moment $M = iA \Rightarrow M = \dfrac{ev}{2\pi r} \times \pi r^2$ ($\because A = \pi r^2$). $\therefore M = \dfrac{evr}{2}$.

PROBLEMS

08. A circular coil of wire consisting of 100 turns, each of radius 8.0 cm carries a current of 0.40 A. What is the magnitude of the magnetic field B at the centre of the coil ?

TS May 18; EXERCISE PROBLEM

Sol: Here, $n = 100$, $r = 8\,cm = 8\times10^{-2}\,m$ and $i = 0.40\,A$.

The magnetic field 'B' at the centre $B = \frac{\mu_0 ni}{2r} = \frac{4\pi\times10^{-7}\times100\times0.4}{2\times8\times10^{-2}}$

$\Rightarrow B = \frac{4\times3.14\times4\times10^{-6}}{16\times10^{-2}} = 3.14\times10^{-4}\,T$.

09. A long straight wire carries a current of 35A. What is the magnitude of the field B at a point 20cm from the wire ?

TS June 15; EXERCISE PROBLEM

Sol: Here, $i = 35\,A$ and $r = 20\,cm = 0.2\,m$.

The wire is long and it is considered as an infinite length wire.

The magnetic field $B = \frac{\mu_0}{2\pi}\frac{i}{r} = \frac{2\times10^{-7}\times35}{0.2} = 3.5\times10^{-5}\,T$.

10. A current of 10A passes through two very long wires held parallel to each other and separated by a distance of 1m. What is the force per unit length between them ?

TS Mar 15, 19; AP Mar 15; SOLVED PROBLEM

Sol: Current in 1st conductor $i_1 = 10$ amp, Current in 2nd conductor $i_2 = 10$ amp,

Separation between conductors $r = 1m$

Force per unit length $= \frac{F}{\ell} = \frac{\mu_0}{2\pi}\frac{i_1 i_2}{r} = \frac{2\times10^{-7}\times10\times10}{1} = 2\times10^{-5}\,Nm^{-1}$.

11. A 100 turn closely wound circular coil of radius 10cm carries a current of 3.2 A. What is the field at the centre of the coil ?

AP Mar 19

Sol: $B = \frac{\mu_0 NI}{2R}$ here, $N = 100$, $I = 3.2\,A$ and $R = 0.1\,m$.

Hence, $B = \frac{4\pi\times10^{-7}\times10^2\times3.2}{2\times10^{-1}} = \frac{4\times10^{-5}\times10}{2\times10^{-1}}$. (Using $\pi\times3.2 = 10$)

The direction is given by the right -hand thumb rule.

VERY SHORT ANSWER QUESTIONS (2 MARKS)

12. What is the importance of Oersted's experiment ? **May 14; AP Mar 20, May 18; TS Mar 17**

Ans: The importance of oersted's experiment is 'every current carrying conductor produces a magnetic field around it which is perpendicular to current carrying conductor'.

13. What is the principle of a moving coil galvanometer ? **TS May 16**

Ans: When a coil carrying current is placed in a magnetic field, it experiences a torque and hence deflects. ∴ Current in the coil (i) $\propto$ deflecting angle (θ).

14. What is the smallest value of current that can be measured with a moving coil galvanometer, tangent galvanometer ?

Ans: The smallest value of current that can be measured with M.C.G is in the order of $10^{-9}\,A$.

The smallest value of current than can be measured with T.G is in the order of $10^{-6}\,A$.

15. How do you convert a moving coil galvanometer into an ammeter ?

AP June 15, May 18, Mar 19; TS Mar & May 18

Ans: MCG can be converted into ammeter by connecting a low resistance in parallel to it.

16. How do you convert a moving coil galvanometer into a voltmeter ?

TS Mar 15, 16; AP Mar 15, 16, May 18

Ans: MCG can be converted into voltmeter by connecting a high resistance in series to it.

17. Distinguish between ammeter and voltmeter.

AP Mar 15, 17, 18, May 16, 17; TS June 15, Mar 20

Ans:

Ammeter	Voltmeter
1) It is a device used for measuring currents in electrical circuits.	It is a device used for measuring potential difference between two points in a circuit.
2) A moving coil galvanometer is converted into an ammeter by connecting a suitable low resistance in parallel to it.	A moving coil galvanometer is converted into a voltmeter by connecting a suitable high resistance in series with it.
3) The resistance of an ideal ammeter is zero.	The resistance of an ideal voltmeter is infinite.
4) An ammeter should always be connected in series in the circuit.	A voltmeter should always be connected in parallel in the circuit.

18. State Ampere's law and Biot-Savart Law. **TS 19**

Ans: **1) Ampere's law:** The line integral of the intensity of magnetic induction field ($\oint \vec{B} \cdot d\vec{\ell}$) around a closed curve is equal to μ_0 times the net current (I) bounded by the curve.

$$\oint \vec{B} \cdot d\vec{\ell} = \mu_0 I .$$

2) Biot - Savart Law: The intensity of magnetic induction (dB) due to a small element is directly proportional to

i) current (i), ii) length of the element ($d\ell$), iii) sine angle between radius vector (r) and $d\ell$ and iv) inversely proportional to the square of the point from the current element.

Hence, $dB \propto \frac{id\ell \sin\theta}{r^2}$ (or) $dB = \frac{\mu_0}{4\pi} \cdot \frac{id\ell \sin\theta}{r^2}$.

19. A circular coil of radius 'r' having 'N' turns carries a current 'i'. What is its magnetic moment?

TS 17

Ans: Magnetic moment, $M = NiA$ ($\because$ Area $A = \pi r^2$) $\Rightarrow M = Ni(\pi r^2)$.

20. What is the force on a conductor of length 'L' carrying current 'i' placed in a magnetic field of induction B ? When does it becomes maximum.

Ans: i) Force on a conductor $(F) = BiL\sin\theta$

ii) If $\theta = 90°$, $F_{max} = BiL$ i.e., Force on a conductor in a magnetic field is maximum when it is perpendicular to the field.

*** THE END***

08 Magnetism and Matter

LAQ (0) - 0 × 8 = 0M
SAQ (0) - 0 × 4 = 0M
VSAQ(2) - 2 × 2 = 4M
Total Marks = 4M

PROBLEMS

01. A bar magnet of length 0.1 m and with a magnetic moment of 5 Am^2 is placed in a uniform magnetic field of intensity 0.4 T, with its axis making an angle of 60° with the field. What is the torque on the magnet ?

Mar 14; SOLVED PROBLEM

Sol: $M = 5\ Am^2,\ B = 0.4\ T,\ \theta = 60°.\quad \tau = MB\sin\theta = 5\times0.4\sin60° = 2\left(\frac{\sqrt{3}}{2}\right) = 1.732\ Nm.$

02. The earth's magnetic field at the equator is approximately 0.4 G. Estimate the earth's dipole moment.

AP Sep 21; EXAMPLE PROBLEM

Sol: The equatorial magnetic field is $B_E = \frac{\mu_0 M}{4\pi r^3} \Rightarrow M = \frac{B_E 4\pi r^3}{\mu_0}$.

We are given that $B_E = 0.4\ G = 4\times10^{-5}\ T$. For 'r', we take the radius of the earth as $6.4\times10^6\ m$.

Hence, $M = \frac{4\times10^{-5}\times4\pi\times(6.4\times10^6)^3}{4\pi\times10^{-7}} = 4\times10^2\times262.14\times10^{18} \Rightarrow M = 1048.5\times10^{20} = 1.05\times10^{23}\ Am^2$.

This is close to the value $8\times10^{22}\ Am^2$ quoted in geomagnetic texts.

VERY SHORT ANSWER QUESTIONS (2 MARKS)

03. A magnetic dipole placed in a magnetic field experiences a net force. What can you say about the nature of the magnetic field ?

Ans: When a magnet is suspended in uniform magnetic field, then the two poles experience same magnitude of force but in opposite direction. Net force acting on the magnet is zero.

$F_{net} = m(B_1 \sim B_2) = 0 \qquad (\because B_1 = B_2)$

When a magnet is suspended in non-uniform magnetic field, then net force exists

$F_{net} = m(B_1 \sim B_2) \qquad (\because B_1 \neq B_2)$

So the nature of the magnetic field is non uniform magnetic field.

04. What is the magnetic moment associated with a solenoid ?

TS Mar 18, 20

Ans: The magnitude of the magnetic moment of the solenoid is

$M =$ Total number of turns × Current × Cross-sectional area

$M = NiA = Ni\pi r^2$ (r = radius, N = Total number of turns).

05. Magnetic lines form continuous closed loops. Why ?

AP Mar 16, 19, May 18; TS Mar 17, May 18

Ans: Since, isolated magnetic poles do not exist, magnetic lines forms continuous closed loops.

06. State Gauss's law in magnetism.

TS Mar 19

Ans: The net magnetic flux through any closed surface is always equal to 'zero'. i.e., $\int \vec{B}\cdot d\vec{S} = 0$.

07. Define magnetic declination. **Mar 14; AP May 16, 17, Mar 18; TS May 16, 17, 18, Mar 18, 20**

Ans: **Magnetic declination (θ):** At a given place, the angle between geographical meridian and magnetic meridian of earth is called as magnetic declination (θ).

08. Define magnetic inclination (or) angle of dip. **AP Mar 15, 17, 20; TS Mar 15**

Ans: The angle of dip (δ) at a place is defined as the angle made by the direction of earth's magnetic field with the horizontal direction in magnetic meridian.

09. What happens to compass needle at the Earth's poles ? **May 14; TS Mar 17, 19**

Ans: Compass needle does not work at magnetic poles of the earth because, at poles horizontal component of earth's magnetic field is zero. i.e., $B_H = 0$.

10. To what direction, compass needle points at poles ? Which needle is to be used at poles. **TS Mar 19**

Ans: Compass needle can points to any direction, since horizontal component of earth's field is negligible near poles.

11. What do you understand by the "magnetisation" of sample ? **AP Mar 16**

Ans: When a magnetic material is magnetised, the induced magnetic dipole moment per unit volume is known as intensity of magnetisation. i.e., $I = \frac{M}{V}$, unit: Am^{-1}.

12. What are the S.I units of magnetic moment, magnetic induction and magnetic field ? **TS Mar 16; AP Mar 16, May 16, 17**

Ans: **i)** Magnetic moment (M) : A-m^2

ii) Magnetic induction (B) : $\frac{N}{A\text{-}m}$ (or) $\frac{J}{A\text{-}m^2}$ (or) $\frac{Wb}{m^2}$ (or) tesla (T)

iii) Magnetic field (H) : A / m.

13. Define magnetic susceptibility of a material. **AP Mar 15**

Ans: **Magnetic susceptibility (χ):** The ratio of magnitude of intensity of magnetisation to that of magnetising field is called magnetic susceptibility. i.e., $\chi = \frac{I}{H}$.

It is a scalar with no units and dimensions.

14. Classify the following materials with regard to magnetism: **AP Mar 15, 16, 17, 18, 19, 20; TS Mar 15, 16**

i) Manganese **ii) Cobalt** **iii) Nickel** **iv) Bismuth**
v) Oxygen **vi) Copper**

Ans: **i)** Manganese: Paramagnetic material **ii)** Cobalt: Ferromagnetic material
iii) Nickel: Ferromagnetic material **iv)** Bismuth: Diamagnetic material
v) Oxygen: Paramagnetic material **vi)** Copper: Diamagnetic material

15. The earth's magnetic field at the equator is approximately 0.4 G, Estimate the earth's dipole moment. **AP Sep 21; EXAMPLE PROBLEM**

Ans: The equatorial magnetic field is $B_E = \frac{\mu_0 M}{4\pi r^3} \Rightarrow M = \frac{B_E 4\pi r^3}{\mu_0}$.

We are given that $B_E = 0.4\,G = 4\times10^{-5}\,T$. For 'r', we take the radius of the earth as $6.4\times10^6\,m$.

Hence, $M = \frac{4\times10^{-5}\times4\pi\times(6.4\times10^6)^3}{4\pi\times10^{-7}} = 4\times10^2\times262.14\times10^{18} \Rightarrow M = 1048.5\times10^{20} = 1.05\times10^{23}\,Am^2$.

This is close to the value $8\times10^{22}\,Am^2$ quoted in geomagnetic texts.

16. In the magnetic meridian of a certain place, the horizontal component of the earth's magnetic field is 0.26 G and the dip angle is 60°. What is the magnetic field of the earth at this location. **EXAMPLE PROBLEM**

Ans: It is given that $H_E = 0.26\,G$, we have $\cos60° = \frac{H_E}{B_E}$. $\therefore B_E = \frac{H_E}{\cos60°} = \frac{0.26}{(1/2)} = 0.52\,G$.

***** THE END*****

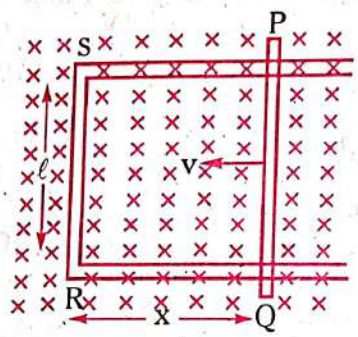
09 Electromagnetic Induction

LAQ (0) - 0 × 8 = 0M
SAQ (1) - 1 × 4 = 4M
VSAQ(0) - 0 × 2 = 0M
Total Marks = 4M

SHORT ANSWER QUESTIONS (4 MARKS)

01. Obtain an expression for the emf induced across a conductor which is moved in a uniform magnetic field which is perpendicular to the plane of motion. **TS May 16**

Ans: Consider a rectangular conductor PQRS in which PQ is free to move. It is placed perpendicular to a uniform magnetic field of induction 'B'.



The rod PQ is moved towards left with a constant velocity 'v'. Rectangular conductor PQRS forms a closed circuit enclosing an area that changes with time as PQ moves.

The magnetic flux ϕ_B enclosed by the loop PQRS is given by $\phi_B = BA\cos 0° = B(\ell x)$

The rate of change of the flux ϕ_B will induce an emf across conductor PQ is given by

$$e = -\frac{d\phi_B}{dt} = -\frac{d}{dt}(B\ell x) \Rightarrow e = -B\ell\frac{d}{dt}(x) \Rightarrow e = B\ell v \left[\because \frac{dx}{dt} = -v\right]$$

This induced e.m.f is called motional emf.

02. Describe the ways in which eddy currents are used to advantage..

AP Mar 15, 16, 17, 18, 19, May 16, 17, 18; TS Mar 15, 18, May 17

Ans: **1) Magnetic braking in trains:** In some electrically powered trains, a metal drum coupled with the wheel of the train which rotates as train is running. In order to apply the brakes, a strong magnetic field is applied across the drum. The eddy currents produced in the drum oppose the motion of the wheel and train stops.

2) Electro magnetic damping: Certain galvanometers have a fixed core made of nonmagnetic metallic material. When the coil oscillates, the eddy currents generated in the core oppose the motion and bring the coil to rest quickly.

3) Induction furnace: Induction furnace can be used to produce high temperatures and can be utilised to prepare alloys by melting the constituent metals. A high frequency alternating current is passed through a coil which surrounds the metals to be melted. The eddy currents generated in the metals produce high temperatures sufficient to melt it.

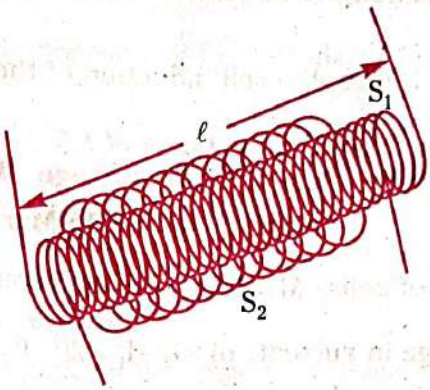
4) Electric power meters: The shiny metal disc in the electric power meter (analogue type) rotates due to the eddy currents. Electric currents are induced in the disc by magnetic fields produced by sinusoidally varying currents in a coil.

5) Eddy currents are used in speedometers of an automobiles.

6) Eddy currents are used in diathermy, that is the deep heat treatment of humanbody.

03. Obtain an expression for the mutual inductance of two long coaxial solenoids. AP Mar 20

Ans: Consider two long air-cored solenoids S_1 and S_2 such that the solenoid S_2 surrounds the solenoid S_1 completely. Both solenoids are of same length 'ℓ' and same cross-sectional area A. Let n_1 and n_2 be the no. of turns per unit length of two solenoids S_1 and S_2 respectively. Let N_1 and N_2 be the total number of turns of solenoids S_1 and S_2 respectively.



If a current i_1 is passed through the solenoid S_1, then the flux linkage with solenoid S_2 is $N_2\phi_2 = M_{21}i_1$, where M_{21} is the mutual inductance of solenoid S_2 with respect to S_1.

$\Rightarrow N_2(B_1 A\cos 0°) = M_{21}i_1$ ($\because$ where B_1 is magnetic field induction due to inner solenoid S_1)

$\Rightarrow n_2\ell(\mu_0 n_1 i_1 A) = M_{21}i_1 \Rightarrow \mu_0 n_1 n_2 A\ell = M_{21}$ ——— (1)

Similarly, if a current i_2 is passed through the solenoid S_2, then the flux linkage with solenoid S_1 is $N_1\phi_1 = M_{12}i_2$, where M_{12} is the mutual inductance of solenoid S_1 with respect to S_2.

$\Rightarrow N_1(B_2 A\cos 0°) = M_{12}i_2$ ($\because$ where B_2 is magnetic field induction due to outer solenoid S_2)

$\Rightarrow n_1\ell(\mu_0 n_2 i_2 A) = M_{12}i_2 \Rightarrow \mu_0 n_1 n_2 A\ell = M_{12}$ ——— (2)

From equations (1) and (2), $M_{21} = M_{12} = M$

If a medium of relative permeability μ had been present, then the mutual inductance is given by $M = \mu_0\mu_r n_1 n_2 A\ell = \mu_0\mu_r n_1 n_2 \pi r^2 \ell$.

04. Obtain an expression for the magnetic energy stored in a solenoid in terms of the magnetic field, area and length of the solenoid. TS Mar 20

Ans: The self-induced emf in a coil opposes any change in the current in a circuit. So, work needed to be done against the emf (e) in establishing the current. This work done is stored as magnetic potential energy. For the current I at an instant in a circuit, the rate of work done is given by

$$\frac{dW}{dt} = ei \Rightarrow \frac{dW}{dt} = Li\frac{di}{dt}\left(\because e = L\frac{di}{dt}\right) \Rightarrow dW = Lidi.$$

Total amount of work done in establishing the current 'i' is, $W = \int dW = \int_0^i Lidi$.

Hence, the energy stored in a solenoid is given by $U = \frac{1}{2}Li^2 \Rightarrow U = \frac{1}{2}L\left(\frac{B}{\mu_0 n}\right)^2$ ($\because B = \mu_0 ni$)

$$\Rightarrow U = \frac{1}{2}(\mu_0 n^2 A\ell)\left(\frac{B}{\mu_0 n}\right)^2 \ (\because L = \mu_0 n^2 A\ell) \Rightarrow U = \frac{1}{2\mu_0}B^2 A\ell.$$

PROBLEMS

05. Current in a circuit falls from 5.0A to 0.0 A in 0.1 s. If an average emf of 200 V induced, give as estimate of the self-inductance of the circuit. **14; TS Mar 16; EXERCISE PROBLEM**

Sol: Initial current, $I_1 = 5.0A$, final current, $I_2 = 0.0Å$, change in current, $dI = I_1 - I_2 = 5A$, time taken for the change, $t = 0.1s$, average emf, $e = 200\,V$.

For self-inductance (L) of the coil, we have the relation for average emf as $e = L\frac{di}{dt}$

$\Rightarrow L = \frac{e}{(di/dt)} = \frac{200}{5/0.1} = 4H$. Hence, the self induction of the coil is 4H.

06. A pair of adjacent coils has a mutual inductance of 1.5 H. If the current in one coil changes from 0 to 20A in 0.5s, what is the change of flux linkage with the other coil ?

TS Mar 17, May 18; EXERCISE PROBLEM

Sol: Mutual inductance of a pair of coils, $M = 1.5H$, initial current, $I_1 = 0A$,

final current, $I_2 = 20A$, change in current, $dI = I_2 - I_1 = 20 - 0 = 20A$.

Time taken for the charge, $t = 0.5\,s$.

Induced emf, $e = \frac{d\phi}{dt}$ —— (1), where $d\phi$ is the change in the flux linkage with the coil.

emf is related with mutual inductance as $e = M\frac{d\ell}{dt}$ ——— (2)

Equating equations (1) and (2), we get $\frac{d\phi}{dt} = M\frac{d\ell}{dt} \Rightarrow d\phi = 1.5 \times (20) = 30\,Wb$.

Hence, the change in the flux linkage is 30 Wb.

07. The current in a coil changes from 5A to 10A in 10^{-2} sec then the emf of 50 milli volts is induced in a coil near it. Calculate the mutual inductance of a coil ?

Sol: Change in current $dI = 10 - 5 = 5A$. Time interval $dt = 10^{-2}\,sec$.

Induced emf $e = \left|-M\frac{di}{dt}\right| = 50 \times 10^{-3} \Rightarrow M \times \frac{5}{10^{-2}} = 50 \times 10^{-3} \Rightarrow M = 10^{-4}H$.

VERY SHORT ANSWER QUESTIONS (2 MARKS)

08. State Lenz's law. **TS June 15, Mar 19**

Ans: The direction of the induced emf in a coil is such that it opposes the cause which produces it.

09. What are Eddy currents ? **AP June 15, TS Mar 19**

Ans: The induced circulating currents produced in a metal due to change in magnetic flux linked with the metal are called eddy currents. These currents look like 'eddies' in a fluid and are known as eddy currents.

10. Define Inductance ? **AP & TS June 15**

Ans: Inductance of a coil is the ratio of the flux linked with the coil to current flowing through the coil. i.e., $L = \frac{N\phi}{I}$.

*** THE END ***

10 Alternating Current

LAQ (0) - 0 × 8 = 0M
SAQ (0) - 0 × 4 = 0M
VSAQ(1) - 1 × 2 = 2M
Total Marks = 2M

VERY SHORT ANSWER QUESTIONS (2 MARKS)

01. Write the expression for the reactance of i) an inductor and ii) a capacitor.

TS May 16, Mar 18

Ans: i) Inductive reactance, $X_L = \omega L$.

ii) Capacitive reactance, $X_C = \frac{1}{\omega C}$, where ω = angular frequency, L = inductance, C = capacity.

02. What is the phase difference between AC emf and current in the following: Pure resistor, pure inductor and pure capacitor.

TS Mar 15

Ans: In a pure resistor, there is no phase difference (or phase difference is zero).

In a pure inductor, the current lags behind the emf by a phase difference of $\frac{\pi}{2}$ radian or 90° (or one quarter cycle).

In a pure capacitor, the current leads the emf by a phase difference of $\frac{\pi}{2}$ radian or 90° (or one quarter cycle).

03. When does an LCR series circuit have minimum impedance ?

Ans: When the inductive reactance is equal to the capacitive reactance $(x_L = x_C)$, the impedance of LCR circuit becomes minimum.

$Z = \sqrt{R^2 + (x_L \sim x_C)^2}$ if $x_L = x_C$, $Z = R$.

04. Define power factor. On which factors does power factor depend ?

Ans: It is defined as the ratio of true power to the apparent power of an AC. circuit it is equal to cosine of the phase angle between alternating current and voltage.

$$\cos\phi = \frac{\text{True power}}{\text{Apparent power}} = \frac{P_{avg}}{V_{rms} \cdot I_{rms}}$$

Power factor depends on RMS voltage, RMS current and average power.

05. What is the phase difference between voltage and current when the power factor in LCR series circuit is unity ?

Ans: Power factor, $\cos\phi = 1 \Rightarrow \phi = 0$. i.e., phase difference between voltage and current is 0°.

06. What is meant by wattless component of current ?

TS Mar 17

Ans: **Wattless current:** The current in an AC. circuit is wattless if average power consumed in the circuit is zero.

07. What is the phenomenon involved in the working of a transformer ?

Mar 14; TS Mar 19; AP June 15, Mar 16, May 16, 17, 18

Ans: A transformer works on the phenomenon of mutual induction between two coils.

08. What is transformer ratio ?

AP Mar 20; TS May 18

Ans: It is the ratio of number of turns in the secondary (N_S) winding to the number of turns in the primary (N_P) winding. Transformer ratio $= \frac{N_S}{N_P}$.

09. What type of transformer is used in a 6V bed lamp ? **AP Mar 17**

Ans: Step down transformer.

10. A transformer converts 200 V ac into 2000 V AC. Calculate the number of turns in the secondary if the primary has 10 turns. **AP Mar 18, 19; TS Mar 16**

Ans: $E_P = 200\,V$, $N_P = 10$, $E_S = 2000\,V$, $N_S = ?$. $\therefore \frac{E_S}{E_P} = \frac{N_S}{N_P} \Rightarrow N_S = \frac{E_S}{E_P} \times N_P = \frac{2000}{200} \times 10$.

11. What is transformer ratio ? **AP Mar 20; TS May 18**

Ans: It is the ratio of number of turns in the secondary (N_S) winding to the number of turns in the primary (N_P) winding. Transformer ratio $= \frac{N_S}{N_P}$.

THE END

11 Electromagnetic Waves

LAQ (0) - 0 × 8 = 0M
SAQ (0) - 0 × 4 = 0M
VSAQ(1) - 1 × 2 = 2M
Total Marks = 2M

VERY SHORT ANSWER QUESTIONS (2 MARKS)

01. The charging current for a capacitor is 0.6A. What is the displacement current across its plates ? **AP Mar 20**

Ans: Given $i_c = 0.6\,A$. Since, conduction current outside the capacitor plates is equal to the displacement current between the capacitor plates. i.e., $i_c = i_d$.

$\therefore$ The displacement current $i_d = 0.6\,A$.

02. What is the principle of production of electromagnetic waves ?

Ans: Accelerated charges radiate electromagnetic waves.

03. What is the relation between the amplitude of the electric and magnetic fields in free space for an electromagnetic wave ?

Ans: The amplitude of the electric and magnetic fields in an electro magnetic wave are related as $B_0 = E_0 / C$ (or) $B = E/C$.

04. If the wavelength of electromagnetic radiation is doubled what happens to the energy of photon ? **TS June 15, Mar 16**

Ans: The energy of photon $E = \frac{hc}{\lambda}$, $\lambda' = 2\lambda$, $E' = \frac{hc}{2\lambda} = \frac{E}{2}$

If the wavelength of electromagnetic radiation is doubled, the energy of photons is halved.

05. What is the average wave length of x-rays ?

Ans: X-rays covers wavelength from 10^{-8}m (10 nm) to 10^{-13}m (10^{-4}nm) (or) 0.001 Å to 100 Å.

06. Give two uses of infrared rays ? **May 14; AP Mar 16, 19; TS Mar 17**

Ans: 1) Earth satellites, 2) Both for military purpose and to observe growth of crops,
3) Electronic devices 4) Physical therapy.

07. Write any one of use of infrared rays. Which animal can detect infrared rays ? **TS Mar 19; AP May 17, 18**

Ans: a) i) Infrared rays are used in earth Satellites. ii) To observe the growth of crops.
b) Phythons, snakes and boars can detect the infrared rays.

08. How are microwaves produced ? **AP Mar 15**

Ans: Microwaves with frequencies in the Giga hertz range (GHz) are produced by special vacuum tubes called klystrons, magnetrons and gun diodes.

09. What are the applications of microwaves ? **AP Mar 15, 17, 18, May 15, 16, 18, June 15; TS Mar 15, 17, 18, 20, May 18**

Ans: 1) Micro wave ovens, 2) Aircraft navigation, 3) Automobiles.

10. Microwaves are used in radars. Why ? **Mar 14**

Ans: Due to their short wavelengths, they are suitable for the radar systems used in aircraft navigation.

THE END

12 Dual Nature of Radiation and Matter

LAQ (0) - 0 × 8 = 0M
SAQ (0) - 0 × 4 = 0M
VSAQ(2) - 2 × 2 = 4M
Total Marks = 4M

SHORT ANSWER QUESTIONS (4 MARKS)

01. What is the effect of i) Intensity of light ii) Potential on photoelectric current ?

TS June 15, Mar 19

Ans: **Effect of intensity on photoelectric current:**

1) According to Einsteins photo electric equation, one photon can emit one electron.

2) With increase in intensity of incident radiation, the number of photons incident per second increases.

3) As a result the number of electrons emitted per second also increases, hence the photon current increases. $i \propto I$.

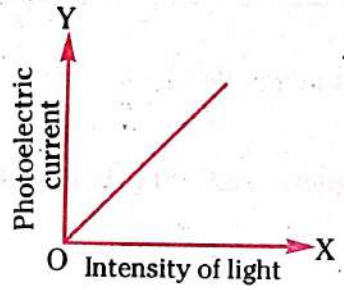
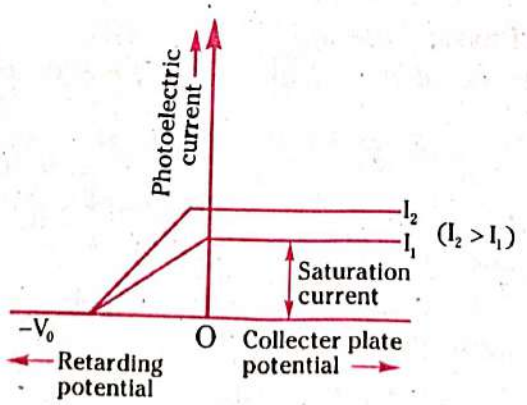


Fig. variation photoelectric current with intensity of light

Effect of potential on photoelectric current:

1) If the positive potential on collector electrode increases, the photo electric current also increases and reaches a maximum value called saturation current.



2) If the negative potential on collector electrode increases, the photo electric current goes on decreasing. At a particular negative potential, the value of photo electric current becomes zero and is known as stopping potential.

3) Stopping potential does not depend on the intensity of incident light. On increasing intensity, the value of saturation current increases whereas the stopping potential remains unchanged.

PROBLEMS

02. The work function of caesium in 2.14 eV. Find
a) the threshold frequency for caesium and
b) the wavelength of the incident light, if the photocurrent is brought to zero by a stopping potential of 0.60 V.
AP Mar 16; EXAMPLE PROBLEM

Sol: a) For the cut-off or threshold frequency, the energy $h\nu_0$ of the incident radiation must be equal to work function ϕ_0, so that

$$\phi_0 = h\nu_0 \Rightarrow \nu_0 = \frac{\phi_0}{h} = \frac{2.14\text{ eV}}{6.63\times10^{-34}} = \frac{2.14\times1.6\times10^{-19}\text{ J}}{6.63\times10^{-34}} = 5.16\times10^{14}\text{ Hz}.$$

Thus, for frequencies less than this threshold frequency, no photoelectrons are ejected.

b) Photocurrent reduces to zero, when maximum kinetic energy of the emitted photoelectrons equals the potential energy eV_0 by the retarding potential V_0. Einstein's photoelectric equation is $eV_0 = h\nu - \phi_0 = \frac{hc}{\lambda} - \phi \Rightarrow \lambda = hc/(eV_0 + \phi_0) = \frac{(6.63\times10^{-34})(3\times10^8)}{(0.6+2.14)}$

$$\Rightarrow \lambda = \frac{19.89\times10^{-26}}{2.74\text{ eV}} = \frac{19.89\times10^{-26}}{2.74\times1.6\times10^{-19}} = 454\text{ nm}.$$

03. The work function of Caesium metal is 2.14 eV. When light of frequency 6×10^{14} Hz is incident on the metal surface, photoemission of electrons occurs. What is the maximum speed of the emitted photoelectrons ?
AP Mar 16; SOLVED PROBLEM

Sol: Given, work function $\phi_0 = 2.14\text{ eV}$, Frequency $\nu = 6\times10^{14}$ Hz

$$K.E_{max} = \frac{1}{2}mv_{max}^2 \Rightarrow v_{max} = \sqrt{\frac{2K.E_{max}}{m}} = \sqrt{\frac{2\times0.54\times10^{-19}}{9.1\times10^{-31}}} = 0.344\times10^6\text{ ms}^{-1} = 344\text{ km/sec}.$$

04. What is the de-Broglie wavelength associated with an electron, accelerated through a potential difference of 100 volts ?
AP Mar 20, Sep 21; EXAMPLE PROBLEM

Sol: Acceleration potential $V = 100\text{ V}$. The de-Broglie wavelength $\lambda = \frac{h}{p} = \frac{1.227}{\sqrt{V}}\text{nm} = 0.1227\text{ nm}$.

The de-Broglie wavelength associated with an electron in this case is of the order of X-ray wavelength.

VERY SHORT ANSWER QUESTIONS (2 MARKS)

05. What are 'cathode rays' ?
AP Mar 17

Ans: A stream of fast moving negatively charged particles are called cathode rays.

06. What is 'Work function' ?
AP May 16, Mar 19; TS Mar 15, 17, 18

Ans: The minimum energy of incident photon required to eject the electrons from a photo metal is known as work function. It is denoted by 'ϕ'. $\phi = h\nu_0$

07. What important fact did Millikan's experiment establish ?

Ans: Millikan's experiment verifies the Einstein's photo electric equation.

08. What is 'Photo electric effect'?
May 14; AP Mar 15, 17, 18, 20; TS Mar 16, 18, May 17

Ans: When a light of sufficient energy is made to incident on a photo metal, electrons are emitted. This phenomena is known as photo electric effect.

09. Give examples of 'Photo sensitive substances'. Why they are called so? **AP May 16, Sep 21**

Ans: **Eg:** Alkali metals such as lithium, sodium, potassium, cesium and rubidium.

They are called so because their work function is low and they emit the photo electrons, when they are illuminated by visible light also.

10. Write down Einstein's photo electric equation ? **Mar 15, 19, May 17; TS May 16, 18**

Ans: **Einstein's photo electric equation** $h\nu = \phi + \frac{1}{2}mv_{max}^2$,

where $\frac{1}{2}mv_{max}^2$ = maximum kinetic energy of photo electrons,

$h\nu$ = photon energy, ϕ = work function $(h\nu_0)$ of metal surface.

11. Write down De Broglie's relation and explain the terms there in.

AP Mar 16, 18; TS Mar 16, 18, May 17

Ans: The De Broglie wavelength associated with a material particle is given by $(\lambda) = \frac{h}{p} = \frac{h}{mv}$.

Where m = mass of the particle, v = velocity of the particle,

h = Planck's constant, p = momentum of the particle.

12. State Heisenberg's uncertainty principle. **Mar 14; TS Mar 17, 20**

Ans: **Statement:** 'It is not possible to measure both the position and momentum of an electron at the same time exactly'.

i.e., $\Delta x \cdot \Delta p \geq \frac{h}{2\pi}$, where Δx = uncertainty in position, Δp = uncertainty in linear momentum.

13. An electron, an α-particle and a proton have the same kinetic energy. Which of these particles has the shortest de Broglie wavelength ? **EXAMPLE PROBLEM, TS Mar 15**

Ans: For a particle de Broglie wavelength, $\lambda = h/p$, Kinetic energy, $K = p^2/2m$

Then, $\lambda = h/\sqrt{2mK}$

For the same kinetic energy 'K', the de-Broglie wavelength associated with particle is inversely proportional to the square root of their masses. A proton $\left({}_1^1H\right)$ is 1836 times massive than an electron and an α-particle four times that of a proton. Hence, α-particle has the shortest de-Broglie wavelength.

14. What is the de-Broglie wavelength associated with an electron, accelerated through a potential difference of 100 volts ? **EXAMPLE PROBLEM; AP Mar 15, 20, Sep 21; TS May 16**

Ans: Acceleration potential V = 100 V. The de-Broglie wavelength $\lambda = \frac{h}{p} = \frac{1.227}{\sqrt{V}}nm = 0.1227\ nm$.

The de-Broglie wavelength associated with an electron in this case is of the order of X-ray wavelength.

THE END

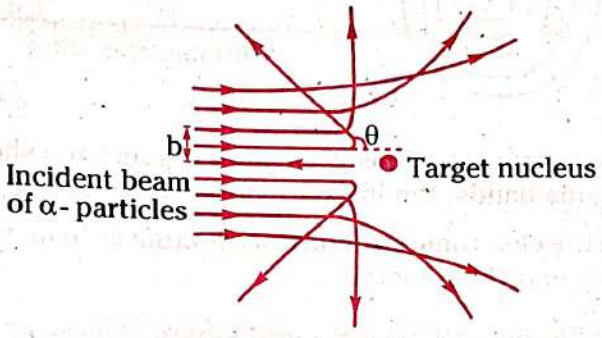
13 Atomic Physics

LAQ (0) - 0 × 8 = 0M
SAQ (1) - 1 × 4 = 4M
VSAQ(0) - 0 × 2 = 0M
Total Marks = 4M

SHORT ANSWER QUESTIONS (4 MARKS)

01. What is impact parameter and angle of scattering ? How are they related to each other ?

Ans: **Impact parameter:** It is the perpendicular distance of the velocity vector of the α - particle from the central line of the nucleus when the α - particle is far away from the nucleus of the atom. It is denoted by 'b'.



α- particle scattering

Angle of Scattering: It is the angle with which α-rays scatter when they are incident towards the nuclei.

The relation between impact parameter and angle of scattering $b = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2\cot(\theta/2)}{(1/2)mv^2}$.

02. Explain distance of closest approach and impact parameter.

Ans: **Distance of closest approach:** It is the minimum distance from the centre of nucleus upto which an energetic α-particle travelling directly towards the nucleus can move during head on collision before coming to rest and retracing its path. It is denoted by r_0.

$$\therefore r_0 = \frac{(Ze)(2e)}{4\pi\varepsilon_0 E} = \frac{2Ze^2}{4\pi\varepsilon_0\left(\frac{1}{2}mv^2\right)}.$$

Impact parameter: It is perpendicular distance of the velocity vector of the α-particle from the centre of the nucleus when it is far away from the atom.

03. Describe Rutherford atom model. What are the drawbacks of this model ? **TS Mar 18**

Ans: **Rutherford nuclear model of atom:**

1) Atom is spherical and mostly hollow.
2) The +ve charge and the mass of the atom is concentrated in a small region at the centre of the atom called nucleus.
3) The radius of nucleus is 10^{-13} to 10^{-15}m and the radius of atom is 10^{-10}m.
4) The electrons present outside the nucleus (called extra nuclear part) are equal in number to protons inside the nucleus.
5) Just as the planets revolve around the sun, the electrons revolve around the nucleus.

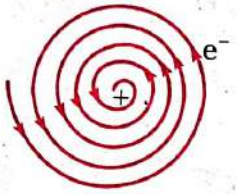
6) The revolving electrons are under the influence of two forces. i.e.,

a) The centripetal force of attraction towards nucleus.

b) The centrifugal force directed away from the orbiting path. These two forces being equal and opposite direction and balance each other and electrons continuously revolve in an orbit.

Drawbacks in Rutherford's model:

1) According to Rutherford's model, if any charged particle moving under the influence of oppositely charged particle then the particle loose energy continuously and come closer and closer to the nucleus and finally falls into the nucleus. Then the atom shall collapse due to the merging of electrons with the nucleus. But it has not happened.



Atomic Spectra

2) If electrons loose energy continuously, the atomic spectrum should have continuous bands. Instead of continuous bands, the lines are observed.

3) It does not explain the electronic structure of the atom as to how the electrons are distributed around the nucleus and their energies.

04. Derive an expression for potential energy and kinetic energy of an electron in any orbit of a hydrogen atom according to Bohr's atomic model. How does PE change with increasing 'n'.

TS Mar & June 15

Ans: As per Bohr's atom model, electrons are reducing around the nucleus in certain permitted orbits.

For electron to revolve in orbit, the electrostatic force and centrifugal force must be equal i.e., $F_c = F_e$.

$$\therefore \frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2} \Rightarrow mv^2 = \frac{e^2}{4\pi\varepsilon_0 r}.$$

$\therefore$ Kinetic energy of electron $K.E = \frac{1}{2}mv^2 = \frac{1}{2}\frac{e^2}{4\pi\varepsilon_0 r} = \frac{e^2}{8\pi\varepsilon_0 r}$ —— (1)

Potential energy between electron and nucleus $U = -\frac{1}{4\pi\varepsilon_0}\frac{e\cdot e}{r} = -\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r}$ —— (2)

–ve sign idicates force of attraction.

Relation between potential energy and radius of orbit:

Potential energy $U = -\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r} \Rightarrow U \propto \frac{1}{r}$ —— (3)

But, $r = \frac{n^2h^2\varepsilon_0}{\pi me^2}$ i.e., $r \propto n^2$ —— (4)

From eq. (3) & (4), Potential energy $U \propto \frac{1}{r} \Rightarrow U \propto \frac{1}{n^2}$.

$\therefore$ Potential energy of orbit is inversly proportional to square of number of orbit (n^2).

05. What are the limitations of Bohr's theory of hydrogen atom ?

Mar 14; AP Mar & May 17; TS May 17, 18, Mar 20

Ans: 1) It could not explain the spectra of complex atoms having more than one electrons.
2) It does not give an idea about the distribution of electrons in an atom.
3) This model could not account for the wave nature of electrons.
4) It does not give any idea about the relative intensity of spectral lines.
5) It does not explain Zeeman effect and Stark effect.

06. State the basic postulates of Bohr's theory of atomic spectra. **AP Mar 16**

Ans: **Basic postulates of Bohr's theory of atomic spectra:**

1) An electron in an atom could revolve in certain stable orbits without the emission of radiant energy.

2) The electron revolves around the nucleus only in those orbits for which the angular momentum is integral multiple of $\frac{h}{2\pi}$ where 'h' is the Planck's constant $(=6.6\times10^{-34}\,Js)$. Thus the angular momentum (L) of the orbiting electrons is quantised.

i.e., $L=\frac{nh}{2\pi}$ —— (1)

3) Electromagnetic radiations are emitted if an electron jumps from stationary orbit of higher energy level E_2 to another stationary orbit of lower energy level E_1.

$h\nu = E_2 - E_1$ —— (2)

where E_1 and E_2 are the energies of lower and higher energy levels.

07. Explain different types of spectral lines.

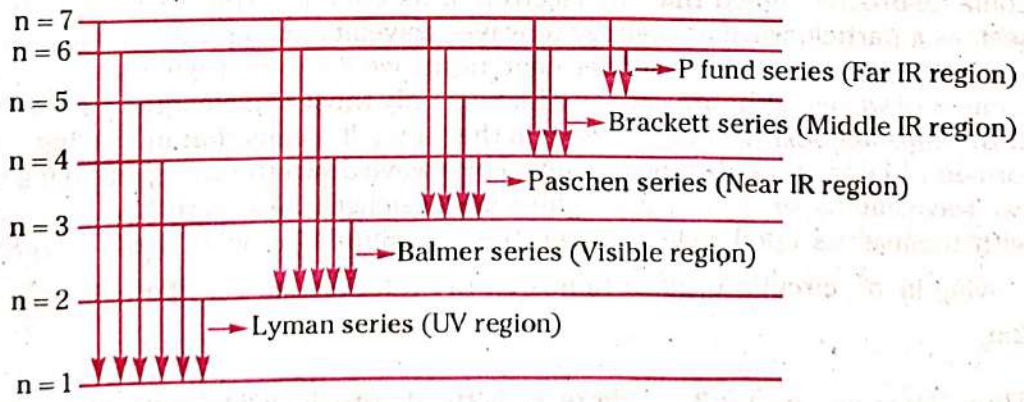
AP June 15, Mar 15, 19, May 16, 18; TS Mar & May 16

Ans: There are the following series of spectral lines:

Lyman series: It is the series in which the spectral lines correspond to the transition of electron from some higher energy states to the lower energy state $n_f = 1$.

$$\bar{\nu}=\frac{1}{\lambda}=R_H\left[\frac{1}{1^2}-\frac{1}{n_i^2}\right] \text{ where } n_i = 1,2,3,4...$$

This lies in UV region of spectra



Balmer Series: It is the series in which spectral lines correspond to the transition of electron from some higher energy states to the lower energy state $n_f = 2$.

$$\bar{\nu}=\frac{1}{\lambda}=R_H\left[\frac{1}{2^2}-\frac{1}{n_i^2}\right] \text{ where } n_i = 3,4,5,....$$

This lies in visible region of spectra.

Pashen Series: It is the series in which spectral lines correspond the transition of electron from some higher energy states to the lower energy state $n_f = 3$.

$\bar{\nu} = \frac{1}{\lambda} = R_H\left[\frac{1}{3^2} - \frac{1}{n_i^2}\right]$, where $n_i = 4,5,6,....$

This lies near IR region of spectra.

Brackett Series: It is series obtained by the transition of electron from some higher energy states to the lower energy state $n_f = 4$.

$\bar{\nu} = \frac{1}{\lambda} = R_H\left[\frac{1}{4^2} - \frac{1}{n_i^2}\right]$, where $n_i = 5,6,7,....$ This lies in the middle of IR region of spectra.

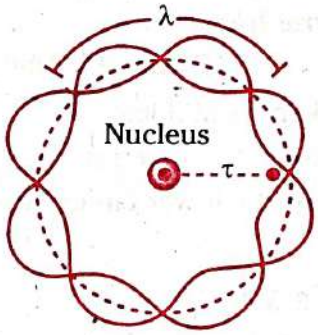
Pfund Series: It is the series obtained by the transition of electron from some higher energy state to the lower energy state $n_f = 5$.

$\bar{\nu} = \frac{1}{\lambda} = R_H\left[\frac{1}{5^2} - \frac{1}{n_i^2}\right]$ where $n_i = 6,7,8,....$

This lies farther from the IR region of spectra.

08. Write a short note on De-Broglie's explanation of Bohr's second postulate of quantization. **TS Mar 17**

Ans: According to Bohr's second postulate, the angular momentum of an electron orbiting around the nucleus is quantized.



Louis de-Broglie argued that the electron in its circular orbit, as proposed by Bohr, must be seen as a particle wave. In analogy to waves travelling on a string, particle waves too can lead to standing waves under resonant conditions. We know that when a string is plucked, a vast number of wavelengths are excited. However only those wavelengths survive which have nodes at the ends and form a standing wave in the string. It means that in a string, standing waves are formed when the total distance travelled by a wave down the string and back is one wavelength, two wavelengths, or any integral number of wavelengths. Waves with other wavelengths interfere with themselves upon reflection and their amplitudes quickly drop to zero. For an electron moving in n^{th} circular orbit of radius r_n, the total distance is the circumference of the orbit, $2\pi r_n$.

Thus, $2\pi r_n = n\lambda$, $n = 1,2,3,....$ where λ_n is the de Broglie wavelength of electron in n^{th} orbit.

If the speed of the electron is much less than the speed of light, the momentum is mv_n.

Thus $\lambda = \frac{h}{mv_n}$ —— (1); From eq. (1), we have $2\pi r_n = \frac{nh}{mv_n} \Rightarrow mv_n r_n = \frac{nh}{2\pi}$.

This is the quantum condition proposed by Bohr for the angular momentum of the electron.

PROBLEMS

09. The wavelength of first member of Balmer series is 6563Å. Calculate the wavelength of second member of Lyman series. **AP Mar 20; SOLVED PROBLEM**

Sol: For first member of Balmer series, $n_1 = 2$ and $n_2 = 3$.

$$\therefore \frac{1}{\lambda_1} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36} \Rightarrow \lambda_1 = \frac{36}{5R} \quad \text{—— (1)}$$

For second member of Lyman series, $n_1 = 1$ and $n_2 = 3$.

$$\therefore \frac{1}{\lambda_1} = R\left[\frac{1}{1^2} - \frac{1}{3^2}\right] = R\left[1 - \frac{1}{9}\right] = \frac{8R}{9} \Rightarrow \lambda_1 = \frac{9}{8R} \quad \text{—— (2)}$$

Dividing (2) by (1), we get $\frac{\lambda_2}{\lambda_1} = \frac{9}{8R} \times \frac{5R}{36} = \frac{5}{32} \Rightarrow \lambda_2 = \frac{5}{32}\lambda_1 = \frac{5}{32} \times 6563 \text{ Å} = 1025.5 \text{ Å}$.

10. The Lyman series of hydrogen spectrum lies in the ultraviolet region. Why ? **AP Mar 15**

Sol: The wave length of the spectral lines in Lyman series is less than 3900 Å. So, the Lyman series lies in U.V. region.

THE END

14 Nuclear Physics

LAQ (I) - 1 × 8 = 8M
SAQ (0) - 0 × 4 = 0M
VSAQ(0) - 0 × 2 = 0M
Total Marks = 8M

LONG ANSWER QUESTIONS (8 MARKS)

01. Define mass defect and binding energy. How does binding energy per nucleon vary with mass number. What is its significance ?

Ans: **Mass defect:** The difference between the total mass of all the nucleons of the nucleus and the actual mass of the nucleus is called the mass defect (Δm).

Consider a nucleus of mass number 'A' and atomic number 'Z'.

Let m_p = the mass of each proton, Zm_p = the total mass of protons,

m_n = the mass of each neutron, $(A-Z)m_n$ = the total mass of neutrons,

m_N = the mass of the nucleus.

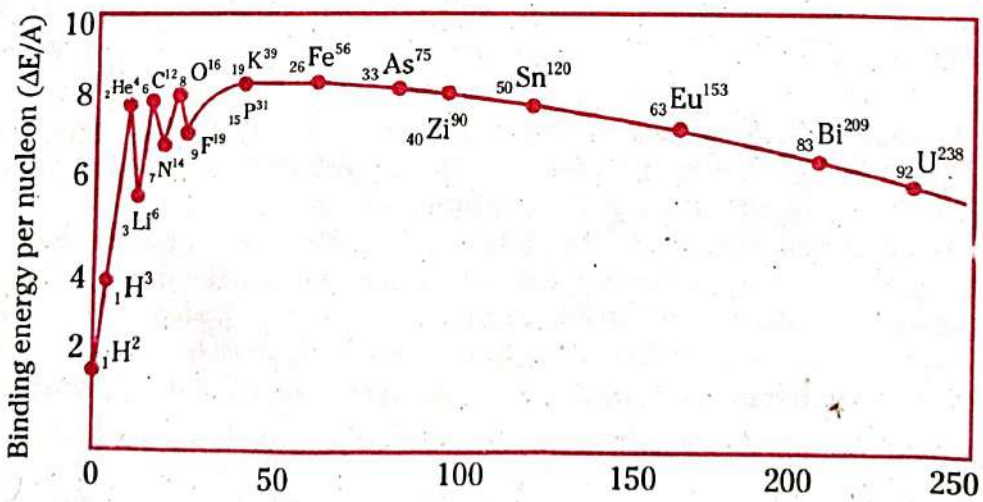
$\therefore \Delta m = [Zm_p + (A-Z)m_n] - m_N$

Binding energy: The binding energy is defined as the energy released when protons and neutrons combine to form a nucleus" (or) 'It is also defined as the energy required to break the nucleus into its constituent protons and neutrons'.

Binding energy $(\Delta E) = \Delta m \cdot c^2$ (according to mass-energy relation), where 'c' is the velocity of light.

Average binding energy or binding energy per nucleon: $\dfrac{\text{Binding energy of nucleus}}{\text{Mass number}} = \dfrac{\Delta E}{A}$.

Variation of binding energy with mass number: The graph describes how the binding energy per nucleon varies with mass number A.



Binding energy per nucleon (ΔE / A) versus the Mass number (A)

Salient features:

The binding energy per nucleon increases with an increase of mass number and reaches a maximum of 8.75 MeV for $A = 56$ (Iron) and then decreases to 7.6 MeV for $A = 238$ (Uranium).

Iron has maximum value 8.75 MeV, hence it is the most stable element.

The value of B.E per nucleon is close to the maximum value for the elements of range $30 < A < 170$.

In the region of smaller mass number, $^{4}_{2}He$, $^{12}_{6}C$ and $^{16}_{8}O$ have maximum B.E than those elements $^{6}_{3}Li$, $^{10}_{5}B$ and $^{14}_{7}N$ which are nearby. The nuclei having even number of protons are more stable than those of odd number of protons.

Let us consider three nuclei like uranium, helium and iron. Uranium has low B.E per nucleon as 7.6 MeV. Hence to attain greater stability uranium breaks up into intermediate mass nucleus. This phenomenon is called nuclear fission.

The lighter nuclei having low B.E per nucleon like hydrogen combine to form a helium for greater stability. This is called nuclear fusion.

Iron has maximum B.E per nucleon i.e., 8.75 MeV is most stable and will undergo neither fission nor fusion.

B.E per nucleon determines the stability of the nucleus.

02. What is radioactivity ? State the law of radioactive decay. Show that radioactive decay is exponential in nature.

TS Mar 16, May 16, 18

Ans: **Radioactivity:** The nuclei of certain elements disintegrate spontaneously by emitting alpha (α), beta (β) and gamma (γ) rays. This phenomenon is called natural radioactivity. To attain stability, certain heavy nuclei exhibits natural radioactivity.

Radioactive decay law: The rate of radioactive decay $\left(-\frac{dN}{dt}\right)$ is directly proportional to the number of nuclei (N) present at that time.

Consider a radioactive sample. Let initial number of nuclei $= N_0$

Number of nuclei remain at time 't' is N.

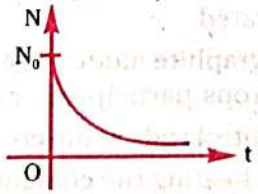
$$\therefore -\frac{dN}{dt} \propto N \Rightarrow \frac{dN}{dt} = -\lambda N \quad \text{——} \quad (1)$$

where 'λ' is the proportionality constant called decay constant or disintegration constant.

The negative sign in the equation indicates the decrease in the number of nuclei with increase in time.

$$\therefore \frac{dN}{N} = -\lambda dt \quad \text{——} \quad (2)$$

On integrating, $\log_e N = -\lambda t + C$ where 'C' is the integration constant.



But, when $t = 0$ the number of nuclei present is N_0. $\therefore \log_e N_0 = C$

The equation (3) becomes,

$$\log_e N = -\lambda t + \log_e N_0 \Rightarrow \log_e N - \log_e N_0 = -\lambda t \Rightarrow \log_e \frac{N}{N_0} = -\lambda t \Rightarrow \frac{N}{N_0} = e^{-\lambda t}$$

$$\therefore N = N_0 e^{-\lambda t} \quad \text{——} \quad (4)$$

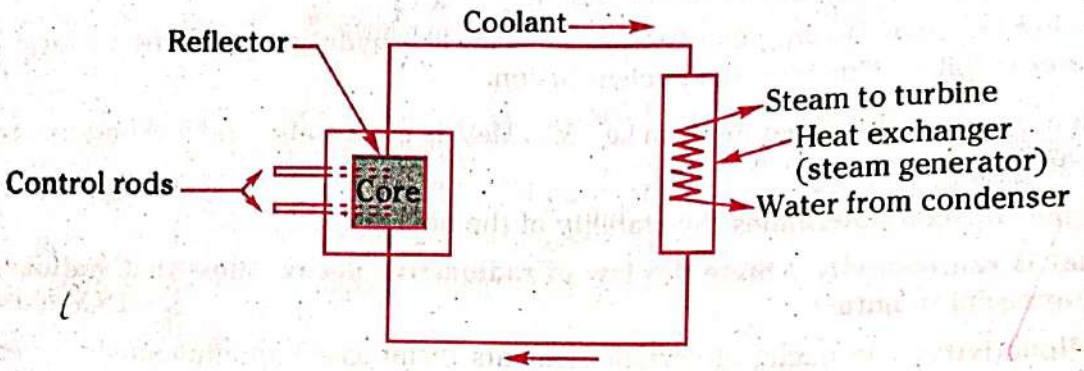
This expression represents the radioactive decay law. This expressions shows that the radioactive sample decreases exponentially with time.

This is constant for a given sample.

03. Explain the principle and working of a nuclear reactor with the help of a labelled diagram.
AP Mar 15, 16, 17, 18, 19, 20, May 16, 17, 18, June 15; TS Mar 15. 17, 18, 19, 20, May 17

Ans: **Principle:** A nuclear reactor is a device which works on the principle of controlled chain reaction. It is also called an 'atomic pile'.

Figure shows the schematic diagram of a nuclear reactor. The core of the nuclear reactor is the place where nuclear fission process takes place.



The essential components of a nuclear reactor are

1) Fuel, 2) Moderator, 3) Control rods, 4) Radiation shielding, 5) Coolant.

1) Fuel: The fissionable materials used in the reactor is called nuclear fuel. The nuclear fuel is taken in the form of rods and sealed in aluminium cylinders.

Eg: Enriched uranium, U^{235}, enriched plutonium or U^{233} etc.

2) Moderator: Moderator is a substance which slows down the fast moving neutrons produced during the nuclear fission process. The average energy of neutrons released in the fission process is 2 MeV. They will slow down to thermal neutrons (0.025 eV) by moderator.

Eg: Heavy water, graphite, hydrocarbon plastics etc.

3) Control rods: The fission rate in the reactor is controlled by using the neutron absorbing materials.

4) Shielding: During fission reaction, beta (β) and gamma (γ) radiation are emitted along with neutrons. Suitable shielding such as steel, lead and concrete walls are provided around the reactor to absorb and reduce the intensity of radiation.

5) Coolant: The heat generated in fuel elements is removed by using a suitable coolant to flow around them. The coolants used are water at high pressures, molten sodium etc.

Working: Uranium fuel rods are placed in the aluminium cylinders, which are separated by some distance. The graphite moderator is placed in between the fuel cylinders.

The control rods are kept in the holes of the graphite block. When a few U-235 nuclei undergo fission, fast neutrons are liberated.

These neutrons pass through graphite moderator and loose their energy to become thermal neutrons. These thermal neutrons participate in further fission process.

By proper adjustment of the control rods in the core, the fission events are suitably controlled.

The heat generated is used for heating the coolant. Heat is transferred to water and steam is produced. This steam is used to run the turbine. This turbine is used to drive a generator to produce electricity.

04. Explain the source of stellar energy. Explain the carbon-nitrogen cycle and proton-proton cycle occurring in stars ?
TS June 15

Ans: The energy of the sun and the brightest stars is produced by nuclear fusion is called stellar energy. Sun and stars have been radiating huge amount of energy by nuclear fusion reactions taking place in core, where the temperature is of the order of 10^7 K.

Carbon-Nitrogen cycle: According to Bethe-Weizsacker, the Carbon-Nitrogen cycle consists of a chain of nuclear reaction in which protons combine to form Helium, with the help of carbon and nitrogen as catalysts.

The reactions are given below:

$_1H^1 + _6C^{12} \rightarrow _7N^{13} + \gamma - ray$

$_7N^{13} \rightarrow _6C^{13} + _1e^0 + \nu$ (neutrino)

$_1H^1 + _6C^{13} \rightarrow _7N^{14} + \gamma - ray$

$_1H^1 + _7N^{14} \rightarrow _8O^{15} + \gamma - ray$

$_8O^{15} \rightarrow _7N^{15} + _1e^0 + \nu$ (neutrino)

$_1H^1 + _7N^{15} \rightarrow _6C^{12} + _2He^4$

The net reaction is $4_1H^1 \rightarrow _2He^4 + 3\gamma + 2_{+1}e^0 + 2\nu$.

The energy released during this process is 26.7 MeV. This cycle begins in stars at a temperature of about 2×10^7 K.

Proton-Proton cycle: The fusion reaction in the sun is a multi-step process in which the hydrogen is burned into helium.

Thus, the fuel in the sun is the hydrogen in its core.

The proton-proton (p, p) cycle by which fusion occurring is represented by the following sets of reactions:

$_1H^1 + _1H^1 \rightarrow _1H^2 + _1e^0 + \nu$

$_1H^2 + _1H^1 \rightarrow _2He^3 + \gamma$

The above two reactions should take place twice so that the following reaction occurs

$_2He^3 + _2He^3 \rightarrow _2He^4 + _1H^1 + _1H^1 + Q$.

The net reaction is $4_1H^1 \rightarrow _2He^4 + 2_{+1}e^0 + 2\nu + 2\gamma$

The energy released during this process is 26.7 MeV.

This is the source of energy release in stars called red-dwarfs.

SHORT ANSWER QUESTIONS (4 MARKS)

05. Distinguish between nuclear fission and nuclear fusion.

Ans:

Fission	Fusion
1) In this process, heavy nucleus is divided into two fragments along with few neutrons.	In this process, lighter nuclei will combine together to produce heavy nucleus.
2) In this process, neutrons are liberated.	In this process, positrons are liberated.
3) It takes place at ordinary temperature and pressure.	It takes place at high temperature and pressure.
4) Radio isotopes are released.	No trace of radio isotopes.
5) The principle involved in atom bomb is fission.	The principle involved in hydrogen bomb is fusion.
6) It can be controlled.	It can't be controlled.
7) The energy released per nucleon is 0.85 MeV.	The energy released per nucleon is 6.7 MeV.
8) A slow moving neutron is required to initiate this process.	Except fusing materials, no other particle is required to initiate this process.

PROBLEMS

06. Compare the radii of two nuclei with mass numbers 27 & 64. AP Mar 20; SOLVED PROBLEM

Sol: Let $A_1 = 27$, $A_2 = 64$, $\frac{R_1}{R_2} = ?$

We know $R \propto A^{1/3} \Rightarrow \frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{27}{64}\right)^{1/3} = \left(\frac{3^3}{4^3}\right)^{1/3} = \frac{3}{4}$ $\therefore R_1 : R_2 = 3:4$.

07. Calculate the energy equivalent of 1g of substance. EXAMPLE PROBLEM

Sol: Energy, $E = mc^2 \Rightarrow E = 10^{-3} \times (3\times10^8)^2 J$

$\Rightarrow E = 10^{-3} \times 9\times10^{16} = 9\times10^{13} J$.

Thus, if one gram of matter is converted to energy, there is a release of an enormous amount of energy.

08. The half life of radium is 1600 years. How much time does 1 g of radium takes to reduce to 0.125 g. May 16, 18; SOLVED PROBLEM

Sol: $T_{1/2} = 1600$, $\frac{M}{M_0} = \frac{1}{2^n}$, where n = number of half lives.

$\Rightarrow \frac{125}{1000} = \frac{1}{2^n} \Rightarrow \frac{1}{8} = \frac{1}{2^n} \Rightarrow \frac{1}{2^3} = \frac{1}{2^n} \Rightarrow n = 3$

Time of decay $t = nT_{1/2} \Rightarrow t = 3\times1600 = 4800$ years.

09. If one microgram of $^{235}_{92}U$ is completely destroyed in an atom bomb, how much energy will be released ? AP Mar 19; SOLVED PROBLEM

Sol: Mass (m) $= 1\,\mu gm = 10^{-6} gm = 10^{-9} kg$.

Energy $E = mc^2 = 10^{-9} \times (3\times10^8)^2 = 10^{-9} \times 9\times10^{16} = 9\times10^7$ J.

10. How much ^{235}U is consumed in a day in an atomic power house operating at 400 MW, provided the whole of mass ^{235}U is converted into energy. SOLVED PROBLEM; AP Mar 11

Sol: $t = 86400$ sec, $P = 400\times10^6$ W

$$P = \frac{E}{t} = \frac{mc^2}{t} \Rightarrow m = \frac{Pt}{c^2} = \frac{4\times10^8 \times 86400}{(3\times10^8)^2} = 0.384\times10^{-3} kg = 0.384 \text{ gms}.$$

THE END

15 Semiconductor Electronics, Materials, Devices & Simple Circuits

LAQ (0) - 0 × 8 = 0M
SAQ (1) - 1 × 4 = 4M
VSAQ(1) - 1 × 2 = 2M
Total Marks = 6M

SHORT ANSWER QUESTIONS (4 MARKS)

01. Draw and explain the current-voltage (I-V) characteristic curves of a junction diode in forward and reverse bias.

Ans: Voltage-Current (V-I) Characteristics of a junction diode:

Construct the circuit given below to study the (V-I) characteristics of a semiconductor diode

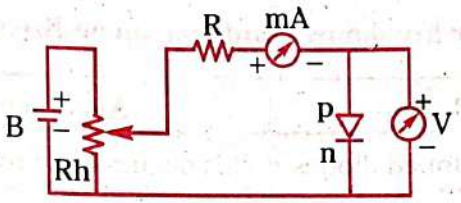


fig. (a)

A semiconductor diode is connected to a battery (B) through a rheostat (Rh) as shown in fig (a).

A milli ammeter (mA) is connected in series to the diode. It is used to measure current. A volt meter V is connected across the diode to measure the voltage (V).

The diode is forward biased and by varying the voltage (V) across the diode, the corresponding current (I) is measured.

The polarity of the diode is reversed so that it gets reverse biased and milli ammeter (mA) is replaced with micro ammeter (μA). The voltage (V) across the diode is varied and the corresponding current is measured.

A graph is drawn between voltage along X-axis and current along Y-axis to study diode V-I characteristics.

Forward Bias:

When the forward bias voltage V_f is increased potential barrier decreases. Initially increase in current is negligible (region OA).

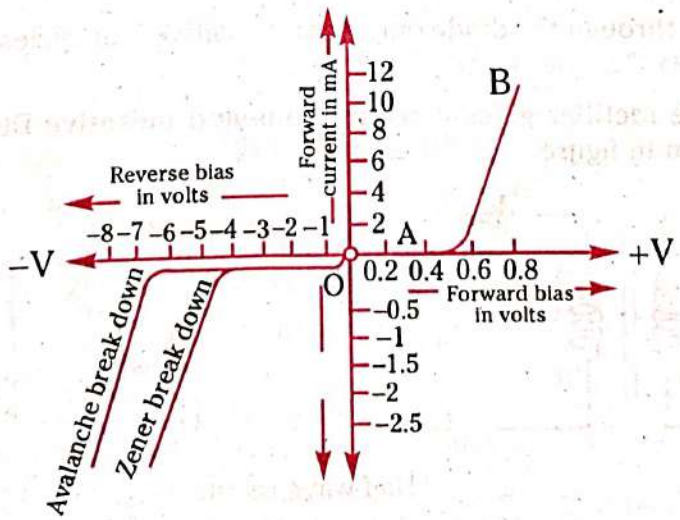


fig (b) p-n junction diode Characteristic curve

Due to the potential barrier for a particular forward voltage V_0 (about 0.3 V for Ge and 0.7V for Si), the current starts increasing significantly. The potential barrier is almost eliminated at this voltage.

This forward voltage V_0 is called threshold voltage or knee voltage. Its value is same as barrier potential V_B.

When the voltage is increased beyond threshold voltage, the forward current increases exponentially (region AB) as shown in the below fig (b).

Reverse Bias: When the diode is reverse biased, a small current of the order of μA flows in the circuit due to minority charge carriers. This is known as reverse current. The reverse current is shown in figure.

As the reverse voltage increased from zero after some voltage the reverse current quickly rises to its maximum or saturation value. This region is named as breakdown region and this voltage is called breakdown voltage. Current in the reverse bias mode is called reverse saturation current.

02. Distinguish between zener breakdown and avalanche Breakdown. **AP Mar 09**

Ans:

Zener break down	Avalanche break down
1) This occurs in heavily doped diodes.	This occurs in lightly doped diodes.
2) It occurs at low reverse bias voltage.	It occurs at high reverse bias voltage.
3) This occurs due to field emission.	This occurs due to ionisaton by collision.
4) Its gives discontinuous and pulsative DC output.	It gives continuous and pulsative DC output.

03. Describe how a semiconductor diode is used as a half wave rectifier.

Mar 14; AP Mar 16; TS Mar 16, May 18

Ans: **Half wave rectifier:** A rectifier which rectifies only either positive or negative half cycles of the AC input is called half wave rectifier.

Construction: A half wave rectifier can be constructed with a single diode 'D', load resistance R_L, transformer and AC input as shown in figure. The DC output is obtained across the load resistance R_L. The circuit is as shown in figure.

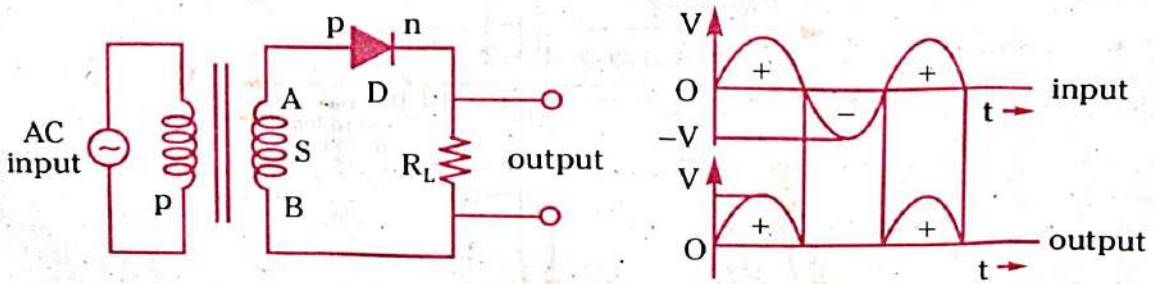
Working: The AC voltage across the secondary winding 'AB' changes polarity after every half cycle.

During positive half cycle the diode is forward biased and current flows through the diode.

During the negative half cycle, the diode is reverse biased and current does not flow through it.

Thus current flows through the diode only during positive half cycles. Current flows in R_L only in one direction.

Hence, a half wave rectifier gives discontinuous and pulsative DC output across the load resistance as shown in figure.



Half wave rectifier

The efficiency of half wave rectifier is $\eta = \frac{0.406\, R_L}{r_f + R_L}$, r_f is diode forward resistance.

04. What is rectification ? Explain the working of a full wave rectifier.

May 14; AP Mar 15, 18, May 17; TS Mar 15, 19, May 17

Ans: **Rectification:** The process of converting an alternating current into a direct current is called rectification.

Full wave rectifier: A rectifier which rectifies both half cycles of the ac input is called full wave rectifier.

Construction:

A full wave rectifier can be constructed with two diodes D_1 and D_2, centre tap transformer, load resistance R_L and a.c input as shown in figure

In centre tap transformer, the secondary coil is wound into two equal parts. Voltage at A (input of diode D_1) and B (input of diode D_2) with respect to centre tap C are out of phase with respect to each other.

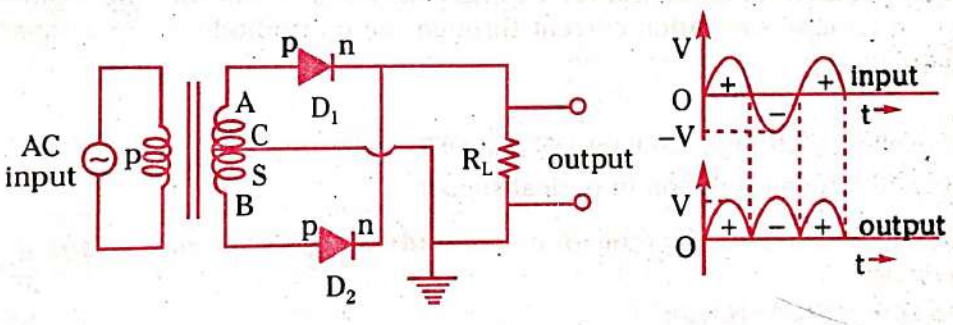
Working:

During the positive half cycles of ac input, diode D_1 is forward biased and diode D_2 is reverse biased. The diode D_2 will not conduct and the current flows through the load resistance R_L is due to D_1.

Similarly, during negative half cycles of AC input, diode D_2 is forward biased and D_1 is reverse biased diode D_1 will not conduct and the current flows through the load resistance R_L due to D_2.

Hence, current flows through the load resistance during both the half cycles and will be in the same direction.

Therefore, using full wave rectifier, the output is continuous but pulsating as shown in figure.



The efficiency of the full wave rectifier is $\eta = \frac{0.812R_L}{r_f + R_L}$, r_f is diode forward resistance.

05. Distinguish between half-wave and full-wave rectifiers.

AP May 16, Mar 17, 19; TS Mar 18, 20, May 18

Ans:

Half wave rectifiers	Full wave rectifiers
1) Only half cycle of AC is converted into DC.	Both cycles of AC are converted into DC.
2) Only one diode is used.	Two diodes are used.
3) Its efficiency is $\eta = \frac{0.406R_L}{r_f + R_L}$.	Its efficiency is $\eta = \frac{0.812R_L}{r_f + R_L}$.
4) Its gives discontinuous and pulsative DC output.	It gives continuous and pulsative DC output.
5) The number of DC output pulses is equal to the frequency of AC input.	The number of DC output pulses is equal to twice the frequency of AC input.

06. What is a photodiode ? Explain its working with a circuit diagram and draw its I-V characteristics.

Ans: **Photodiode:** Photo diode is an optoelectronic device in which current carriers are generated by photons through photo excitation.

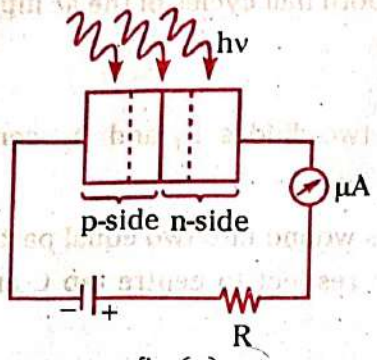


fig. (a)

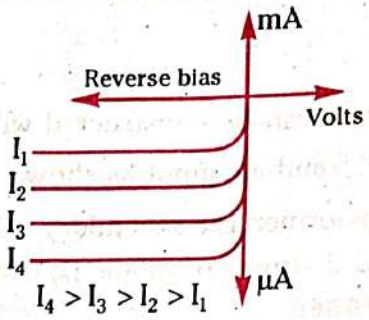


fig. (b)

Working:

When visible light of energy greater than forbidden energy gap is incident on a reverse biased p-n junction photodiode, additional electron-hole pairs are created in the depletion layer (near the junction)

These charge carriers will be separated by the junction field and made to flow across the junction, creating a reverse current across the junction.

The value of reverse saturation current increases with the increase in the intensity of incident light.

V-I Characteristics of photodiode: V-I characteristics of photodiode is shown in figure. It is found that reverse saturation current through the photodiode varies almost linearly with the light flux.

Uses:

1) It is used in switching the light ON and OFF.

2) It is used in demodulation in optical signals.

07. Explain the working of LED and what are its advantages over conventional incandescent low power lamps.

Ans: **Light emitting diode (LED):**

It is a photoelectric device which converts electrical energy into light energy.

It is a heavily doped p-n junction diode which under forward bias emits spontaneous radiation.

The diode is covered with a transparent cover so that the emitted light may come out.

Working:

When p-n junction diode is forward biased, the movement of majority charge carriers takes place across the junction.

The electrons move from n-side to p-side through the junction and holes move from p-side to n-side.

As a result of it, concentration of majority carriers increases rapidly at the junction.

When there is no bias across the junction, there are excess minority carriers on either side of the junction, which recombine with majority carriers near the junction.

On recombination of electrons and holes, the energy is given out in the form of heat and light.

Advantages of LED's over incandescent lamp:

1) LED is cheap and easy to handle.

2) LED has less power and low operational voltage.

3) LED has fast action and requires no warm up time.

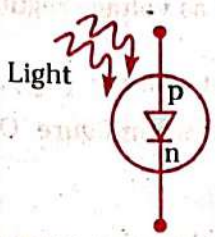
4) LED can be used in burglar alarm system.

08. Explain the working of a solar cell and draw its I-V characteristics.

Ans: Solar cell is a p-n junction device which converts solar energy into electric energy.

Construction:

It consists of a silicon (or) gallium-arsenic p-n junction diode packed in a can with glass window on top.

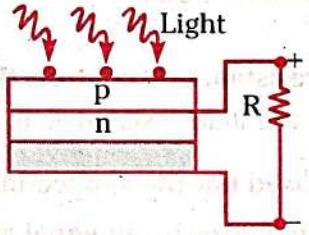


The upper layer is of p-type semiconductor. It is very thin so that the incident light photons may easily reach the p-n junction.

Working:

When light (E = hν) falls at the junction, electron-hole pairs are generated near the junction.

The electrons and holes produced move in opposite directions due to junction field.

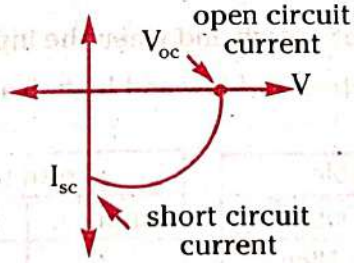


They will be collected at the two sides of the junction giving rise to a photo voltage between top and bottom metal electrodes.

Top metal acts as positive electrode and bottom metal acts as a negative electrode.

When an external load is connected across metal electrodes, a photo current flows.

I-V Characteristics: I-V characteristics of solar cell is drawn in the fourth quadrant of the co-ordinate axes. Because it does not draw current.

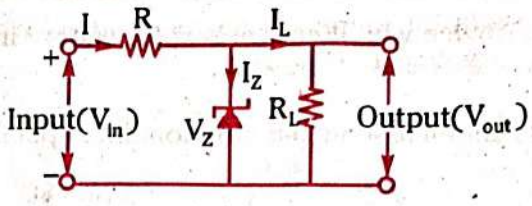


Uses : They are used in calculators, wrist watches, artificial satellites etc.

09. What is a Zener diode? Explain how it is used as voltage regulator ? **TS May 16**

Ans: **Zener Diode:** A properly doped p-n junction diode which has sharp break down voltage when operated in the reverse bias condition is called zener diode.

Zener Diode as Voltage Regulator: A device used to give constant output voltage even when the input voltage changes is called voltage regulator or voltage stabilizers. Zener diode can be used as voltage regulator, when operating in the breakdown region in reverse bias condition.



Zener diode as voltage regulator

Construction: The unregulated input voltage (V_{in}), series resistance R, load resistance R_L and zener diode are connected as shown in figure. Output voltage (V_o) is taken across R_L.

Working:

If the applied input voltage $V_{in} > V_z$, then the zener diode is in breakdown condition and the diode draws large current from the input through the series resistance 'R'.

If 'I' is input current and I_Z and I_L are zener and load currents respectively, then $I = I_Z + I_L$.

$V_{in} = IR + V_Z$ but $V_{out} = V_Z$

$\therefore V_{out} = V_{in} - IR$

The value of 'R' is selected in such a way that in the absence of load 'R_L', maximum safe current flows through the diode.

If input voltage varies, the series resistance 'R' controls the output voltage fluctuations so as to maintain constant voltage even if the load resistance R_L varies.

When the load resistance is increased but the applied input voltage (V_{in}) is fixed, the current I_L decreases and the current I_Z increases by an equal amount so that total current I remains constant.

Hence, the output voltage remains constant. This is the property of zener diode, which works as voltage regulator.

10. Explain the operation of a NOT gate and give its truth table. **TS June 15**

Ans: **NOT Gate:** The NOT gate is a device which has only one input and one output.

The term NOT is represented by bar symbol (–) and the expression $Q = \overline{A}$ indicates that Q equals NOT A.

When the input is low, the output is high and when the input is high, the output is low.

The truth tables of NOT gate in terms of low and high, 0 and 1 are as given below:

Truth table	
Input A	Output Q
Low	High
High	Low

Truth table	
Input A	Output Q
0	1
1	0

The circuit symbol used for the logic gate NOT is as shown in fig (a).

fig. a NOT gate

The circle on the vertex of the triangle represents inversion.

11. Define NAND and NOR gates. Give their truth table. **June 15; Mar 20 ; TS Mar 17**

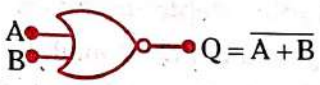
Ans: **NOR Gate:** It consists of two input terminals and one output terminal. The output of a NOR gate is an inversion of the output of an OR gate.

The truth tables of NOR gate is given below:

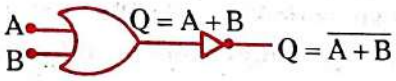
Truth table		
Input		Output
A	B	Q
Low	Low	High
High	Low	Low
Low	High	Low
High	High	Low

Truth table		
Input		Output
A	B	Q
0	0	1
1	0	0
0	1	0
1	1	0

The logical function shown by the truth table is written as A NOR B. The output, $Q = \overline{A+B}$. The symbol for NOR gate is shown in figure.



NOR gate in terms of OR gate is shown in figure.



Therefore, NOR gate = OR gate + NOT gate.

NAND Gate: It consists of two input terminals and one output terminal. The output of a NAND gate is an inversion of the output of an AND gate.

The truth tables of NAND gate in terms of low and high, 0 and 1 are as given below:

Truth table		
Input		Output
A	B	Q
Low	Low	High
High	Low	High
Low	High	High
High	High	Low

Truth table		
Input		Output
A	B	Q
0	0	1
1	0	1
0	1	1
1	1	0

The logical function shown by the truth tables is written as A NAND B. The output $Q = \overline{AB}$. The symbol used for the logic gate is shown in fig (a). NAND gate in terms of AND gate is shown in fig (b).

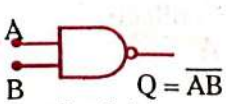


fig. (a)

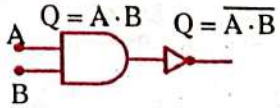


fig. (b)

Hence, NAND gate = AND gate + NOT gate.

VERY SHORT ANSWER QUESTIONS (2 MARKS)

12. What are intrinsic and extrinsic semiconductors ? **AP Mar 15, June 15, May 18**

Ans: **Intrinsic semiconductors :** Pure form of semiconductors are called intrinsic semiconductors.

Extrinsic semiconductors : Semiconductors with the presence of the impurities are called extrinsic semiconductors.

13. What is a p-type semiconductor ? What are the majority and minority charge carriers in it ?
AP Mar 17; TS Mar 17, May 18

Ans: **p-type semiconductor :** When trivalent impurity is added to a pure semiconductor, then it is called p-type semiconductor

In p-type semiconductor majority charge carriers are holes and minority charge carriers are electrons.

14. What is an n-type semiconductor ? What are the majority and minority charge carriers in it ?

Ans: **n-type semiconductor :** When pentavalent impurity is added to a pure semiconductor, then it is called n-type semiconductor.

In n-type semiconductor majority charge carriers are electrons and minority charge carriers are holes.

15. What is a p-n junction diode ? Define depletion layer. **TS May 16, Mar 19**

Ans: A semiconductor like silicon or germanium is doped such that one side of it becomes a p-type and the other side becomes n-type, we get a p-n junction diode. The plane separating the two regions is called p-n junction.

Depletion layer : The narrow region on either side of the junction which becomes free from mobile charge carriers is known as depletion layer.

16. How is a battery connected to a junction diode in i) forward and ii) reverse bias ?
AP May 12

Ans: i) In forward bias, positive terminal of the battery is connected to p-region and negative terminal is connected to n-region of p-n junction diode.

ii) In reverse bias, the positive terminal of the battery is connected to n-region and negative terminal is connected to p-region of p-n junction diode.

17. What happens to the width of the depletion layer in a p-n junction diode when it is i) forward biased and ii) reverse biased ?

Ans: i) In forward bias the width of depletion layer decreases.

ii) In reverse bias the width of depletion layer increases.

18. What is zener voltage (V_z) and how will a zener diode be connected in circuits generally?

Ans: When a zener diode is reverse biased, at a particular voltage the current increases suddenly. The voltage at which the current increases suddenly is called zener voltage (V_z).

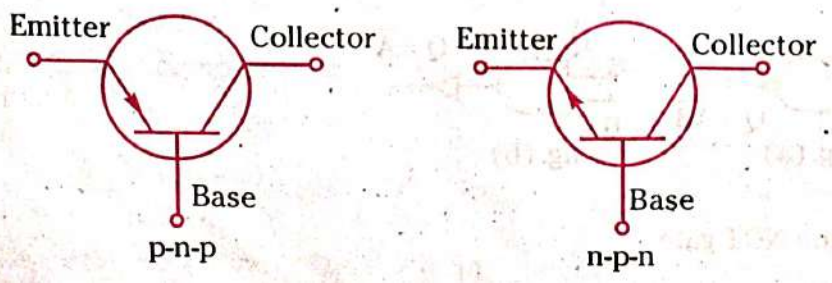
A zener diode is always connected in reverse bias in a circuit.

19. In which bias can a zener diode be used as voltage regulator ? **AP Mar 16, 20; TS June 15**

Ans: Zener diode can be used as a voltage regulator in reverse bias mode.

20. Draw the circuit symbols for p-n-p and n-p-n transistors.
Mar 14; AP May 16, 17, Mar 18; TS Mar 16, 18, May 17

Ans:



21. Which gates are called universal gates ? **TS Mar 15, 20**

Ans: NOR gate and NAND gates are known as universal gates.

22. Write the truth table of NAND gate. How does it differ from AND gate ?

Ans: NAND gate = AND gate + NOT gate .

Truth table of NAND gate

Input		Output
A	B	$Q = \overline{AB}$
0	0	1
1	0	1
0	1	1
1	1	0

The output of NAND gate is output of (AND gate + NOT gate).

THE END

16 Communication System

LAQ (0) - 0 × 8 = 0M
SAQ (0) - 0 × 4 = 0M
VSAQ(1) - 1 × 2 = 2M
Total Marks = 2M

VERY SHORT ANSWER QUESTIONS (2 MARKS)

01. What are the basic blocks of a communication system ? **TS June 15**

Ans: The basic blocks of a communication system are

1) Transmitter, 2) Communication channel, 3) Receiver.

02. Mention the frequency range of speech signals. **AP Mar 20**

Ans: Frequency range of speech signals is 300 Hz to 3100 Hz.

03. What is sky wave propagation ? **AP June 15, May 16**

Ans: In the frequency range from a few MHz upto about 30 MHz, long distance communication can be achieved by ionospheric reflection of radio waves back towards the earth. This mode of propagation is called sky wave propagation and it is used by short wave broadcast services.

04. Which type of communication is employed in mobile phones ?

AP Mar 15, May 18; TS Mar 20

Ans: Space wave communication is employed in mobile phones.

05. Mention the various parts of the ionosphere ? **TS May 16**

Ans: **Various Parts of the Ionosphere:** The various parts of the ionosphere are

1) D (Part of Stratosphere (65 – 70 km day only)),

2) E (Part of Stratosphere (100 km day only)),

3) F_1 (Part of Mesosphere (170 km – 190 km)),

4) F_2 (Part of Thermosphere (300 km at night, 250 – 400 km during day time).

06. Name an appropriate communication channel needed to send a signal of band-width 100 kHz over a distance of 8 km. **CBSE 05**

Ans: Coaxial cables.

07. Define modulation. Why is it necessary ?

Mar 14; AP Mar 16, 17, 18, May 17; TS Mar 15, 16, 19, May 17, 18

Ans: **Modulation:** The process of combining low frequency audio signals with high frequency electromagnetic signals is called modulation.

Necessity of Modulation:

1) Low frequencies cannot be transmitted to long distances.

2) To limit the size of antenna.

3) Power radiated by antenna is less with low frequency.

4) To avoid mixing of signals from different transmitters.

08. Mention the basic methods of modulation ? **AP Mar 16, 19; TS Mar 15, 17, 18**

Ans: **1) Amplitude modulation (AM):** In this method, the amplitude of carrier wave is varied in accordance with the modulating signal, keeping the frequency and phase of carrier wave constant.

2) Frequency modulation (FM): In this method, frequency of carrier wave is varied in accordance with the modulating signal keeping the amplitude and phase of the carrier wave constant.

3) Phase modulation (PM): In this method, phase of carrier wave is varied in accordance with the modulating signal keeping the amplitude and frequency of the carrier wave constant.

09. What is 'World Wide Web' (WWW) ?

Ans: It is an encyclopedia of knowledge accessible to everyone round the clock throughout the year.

THE END

MODEL PAPER-1

PHYSICS, PAPER-II

Time: 3 Hours **Max. Marks: 60**

Note: Read the following instructions carefully.

(i) Answer all questions of Section-A. Answer any six questions of Section-B and any two questions of Section-C.

(ii) In section-A, questions from Sr.No. 1 to 10 are of very short answer type. Each question carries two marks. Every answer may be limited to 5 lines. Answer all these questions at one place in the same order.

(iii) In section-B, questions from Sr.No. 11 to 18 are of short answer type. Each question carries four marks. Every answer may be limited to 10 lines.

(iv) In section-C, questions from Sr.No. 19 to 21 are of long answer type. Each question carries eight marks. Every answer may be limited to 40 lines.

(v) Draw labelled diagrams, wherever necessary for questions in section-B and C.

SECTION-A

I. Answer ALL the following VSAQs: **10 × 2 = 20**

01. What is myopia ? How can it be corrected ?
02. What is the importance of Oersted's experiment ?
03. What are the S.I units of magnetic moment, magnetic induction and magnetic field ?
04. Define magnetic inclination or angle of dip.
05. What is the phenomenon involved in the working of a transformer?
06. If the wavelength of electromagnetic radiation is doubled, what happens to the energy of photon ?
07. What is work function ?
08. What is work function ?
09. Which gates are called universal gates ?
10. Which type of communication is employed in Mobile Phones ?

SECTION-B

II. Answer any SIX of the following SAQs: **6 × 4 = 24**

11. Explain the formation of a rainbow.
12. Explain Doppler effect in light. Distinguish between red.shift and blue shift.
13. Derive the equation for the couple acting on an electric dipole in a uniform electric field.
14. Derive the formula for equivalent capacitance when the capacitors are in series.
15. State & explain Biot-Savart law.
16. Obtain an expression for the mutual inductance of two long coaxial solenoids
17. Write a short note on deBroglie's explanation of Bohr's second postulate of quantization.
18. Explain the working of LED and what are its advantages over conventional incandescent low power lamps.

SECTION-C

III. Answer any TWO of the following LAQs: **2 × 8 = 16**

19. Explain the formation of stationary waves in an air column enclosed in open pipe. Derive the equations for the frequencies of the harmonics produced.
20. State the working principle of potentiometer. Explain with the help of circuit diagram how the potentiometer is used to determine the internal resistance of the given primary cell.
21. Explain the principle and working of a nuclear reactor with the help of a labelled diagram.

******

MODEL PAPER-2

PHYSICS, PAPER-II

Time: 3 Hours **Max. Marks: 60**

Note: Read the following instructions carefully.

(i) Answer all questions of Section-A. Answer any six questions of Section-B and any two questions of Section-C.

(ii) In section-A, questions from Sr.No. 1 to 10 are of very short answer type. Each question carries two marks. Every answer may be limited to 5 lines. Answer all these questions at one place in the same order.

(iii) In section-B, questions from Sr.No. 11 to 18 are of short answer type. Each question carries four marks. Every answer may be limited to 10 lines.

(iv) In section-C, questions from Sr.No. 19 to 21 are of long answer type. Each question carries eight marks. Every answer may be limited to 40 lines.

(v) Draw labelled diagrams, wherever necessary for questions in section-B and C.

SECTION-A

I. Answer ALL the following VSAQs: $10 \times 2 = 20$

01. What is optical density and how is it different from mass density ?
02. How do you convert a moving coil galvanometer into an ammeter ?
03. Define magnetic declination.
04. What is the magnetic moment associated with a solenoid ?
05. What is the phase difference between AC emf and AC current in the following: Pure resistor, pure inductor and pure capacitor.
06. Give two uses of infrared rays.
07. What are cathode rays ?
08. Write down deBroglie's relation and explain the terms therein.
09. Draw the circuit symbols for p-n-p and n-p-n transistors.
10. Define modulation. Why is it necessary ?

SECTION-B

II. Answer any SIX of the following SAQs: $6 \times 4 = 24$

11. Define critical angle. Explain total internal reflection using a neat diagram.
12. Explain Doppler effect in light. Distinguish between red shift and blue shift.
13. Define intensity of electric field at a point. Derive an expression for the intensity due to a point charge.
14. Explain the behaviour of dielectrics in a n external field.
15. Find the magnetic induction due to a long current carrying conductor.
16. Describe the ways in which Eddy currents are used to advantage.
17. Describe Rutherford atom model. What are the draw backs of this model ?
18. Distinguish between Half wave rectifier and full wave rectifier.

SECTION-C

III. Answer any TWO of the following LAQs: $2 \times 8 = 16$

19. a) How are stationary waves formed in closed pipes ? Explain the various modes of vibration and obtain relations for their frequencies.

    b) A closed organ pipe 70 cm long is sounded. If the velocity of sound is $331\ ms^{-1}$, what is the fundamental frequency of vibration of the air column ?

20. State the working principle of potentiometer. Explain with the help of circuit diagram how the potentiometer is used to determine the internal resistance of the given primary cell.
21. Explain the principle and working of a nuclear reactor with the help of a labelled diagram.

*****

MODEL PAPER-3

PHYSICS, PAPER-II

Time: 3 Hours **Max. Marks: 60**

Note: Read the following instructions carefully.

(i) Answer all questions of Section-A. Answer any six questions of Section-B and any two questions of Section-C.

(ii) In section-A, questions from Sr.No. 1 to 10 are of very short answer type. Each question carries two marks. Every answer may be limited to 5 lines. Answer all these questions at one place in the same order.

(iii) In section-B, questions from Sr.No. 11 to 18 are of short answer type. Each question carries four marks. Every answer may be limited to 10 lines.

(iv) In section-C, questions from Sr.No. 19 to 21 are of long answer type. Each question carries eight marks. Every answer may be limited to 40 lines.

(v) Draw labelled diagrams, wherever necessary for questions in section-B and C.

SECTION-A

I. Answer ALL the following VSAQs: **10 × 2 = 20**

01. What is hypermetropia ? How can it be corrected ?
02. Distinguish between ammeter and voltmeter.
03. Magnetic lines form continuous closed loops. Why ?
04. Magnetic lines form continuous closed loops. Why ?
05. What is transformer ratio ?
06. What are applications of microwaves ?
07. Write down deBroglie's relation and explain the terms therein.
08. Write down Einstein's photoelectric equation.
09. In which bias can a Zener diode be used as voltage regulator ?
10. What are the basic blocks of a communication system ?

SECTION-B

II. Answer any SIX of the following SAQs: **6 × 4 = 24**

11. Explain the formation of a mirage.
12. How do you determine the resolving power of your eye ?
13. State and explain Coulomb's law in electricity.
14. Derive the formula for equivalent capacitance when the capacitors are in parallel.
15. Derive an expression for the magnetic induction at the centre of a current carrying circular coil using Biot-Savart law.
16. Obtain an expression for the magnetic energy stored in a solenoid in terms of the magnetic field, area and length of the solenoid.
17. What are the limitations of Bohr's theory of hydrogen atom ?
18. Define NAND and NOR gates. Give their truth tables.

SECTION-C

III. Answer any TWO of the following LAQs: **2 × 8 = 16**

19. What is Doppler effect ? Obtain an expression for the apparent frequency of sound heard when the source is in motion with respect to an observer at rest.
20. State the working principle of potentiometer. Explain with the help of circuit diagram how the emf of two primary cells are compared by using the potentiometer.
21. What is radioactivity ? State the law of radioactive decay. Show that radioactive decay is exponential in nature.

*****

MODEL PAPER-4

PHYSICS, PAPER-II

Time: 3 Hours **Max. Marks: 60**

Note: Read the following instructions carefully.

(i) Answer all questions of Section-A. Answer any six questions of Section-B and any two questions of Section-C.

(ii) In section-A, questions from Sr.No. 1 to 10 are of very short answer type. Each question carries two marks. Every answer may be limited to 5 lines. Answer all these questions at one place in the same order.

(iii) In section-B, questions from Sr.No. 11 to 18 are of short answer type. Each question carries four marks. Every answer may be limited to 10 lines.

(iv) In section-C, questions from Sr.No. 19 to 21 are of long answer type. Each question carries eight marks. Every answer may be limited to 40 lines.

(v) Draw labelled diagrams, wherever necessary for questions in section-B and C.

SECTION-A

I. Answer ALL the following VSAQs: **10 × 2 = 20**

01. Define focal length and radius of curvature of a concave lens.
02. What is the principle of a moving coil galvanometer ?
03. What is the magnetic moment associated with a solenoid ?
04. Define Magnetic susceptibility. Mention its unit.
05. A transformer converts 200 V AC into 2000 V AC. Calculate the number of turns in the secondary if the primary has 10 turns.
06. The charging current for a capacitor is 0.6 A. What is the displacement current across its plates ?
07. Give examples of photosensitive substances. Why are they called so ?
08. State Heisenberg's Uncertainty Principle.
09. What are intrinsic and extrinsic semi-conductors ?
10. Mention the basic methods of modulation.

SECTION-B

II. Answer any SIX of the following SAQs: **6 × 4 = 24**

11. Why does the setting sun appear red ?
12. Derive the expression for the intensity at a point where interference of light occurs. Arrive at the conditions for maximum and zero intensity.
13. Derive an expression for the intensity of the electric field at a point on the axial plane of an electric dipole.
14. Derive an expression for the capacitance of a parallel plate capacitor.
15. State and explain Ampere's law.
16. Obtain an expression for the emf induced across a conductor which is moved in a uniform magnetic field which is perpendicular to the plane of motion.
17. Derive an expression for potential and kinetic energy of an electron in any orbit of a hydrogen atom according to Bohr's atomic model.
18. Describe how a semiconductor diode is used as a half wave rectifier.

SECTION-C

III. Answer any TWO of the following LAQs: **2 × 8 = 16**

19. Explain the formation of stationary waves in stretched strings and hence deduce the laws of transverse waves in stretched strings.
20. State Kirchoff's law for an electrical network. Using these laws deduce the condition for balance in a Wheatstone bridge.
21. Explain the principle and working of a nuclear reactor with the help of a labelled diagram.

*****

MODEL PAPER-5
PHYSICS, PAPER-II

Max. Marks: 60

Time: 3 Hours

Note: Read the following instructions carefully.

(i) Answer all questions of Section-A. Answer any six questions of Section-B and any two questions of Section-C.

(ii) In section-A, questions from Sr.No. 1 to 10 are of very short answer type. Each question carries two marks. Every answer may be limited to 5 lines. Answer all these questions at one place in the same order.

(iii) In section-B, questions from Sr.No. 11 to 18 are of short answer type. Each question carries four marks. Every answer may be limited to 10 lines.

(iv) In section-C, questions from Sr.No. 19 to 21 are of long answer type. Each question carries eight marks. Every answer may be limited to 40 lines.

(v) Draw labelled diagrams, wherever necessary for questions in section-B and C.

SECTION-A

I. Answer ALL the following VSAQs: $10 \times 2 = 20$

01. Define 'power' of a convex lens. What is its unit ?
02. How do you convert a moving coil galvanometer into a voltmeter ?
03. Define magnetic inclination or angle of dip.
04. Classify the following materials with regard to magnetism.
Manganese, Cobalt, Nickel, Bismuth, Oxygen, Copper
05. Write the expression for the reactance of (i) an inductor (ii) a capacitor.
06. Microwaves are used in Radars. Why ?
07. What is photoelectric effect ?
08. Write down deBroglie's relation and explain the terms therein.
09. What is a p-type semiconductor ? What are the majority and minority charge carriers in it ?
10. What is sky wave propagation ?

SECTION-B

II. Answer any SIX of the following SAQs: $6 \times 4 = 24$

11. With a neat labelled diagram explain the formation of image in a simple microscope.
12. Does the principle of conservation of energy hold for interference and diffraction phenomena ? Explain briefly.
13. State Gauss'law in electrostatics and explain its importance.
14. Derive an expression for the electric potential due to a point charge.
15. Derive an expression for the magnetic dipole moment of a revolving electron.
16. Describe the ways in which Eddy currents are used to advantage.
17. Explain the different types of spectral series of Hydrogen atom.
18. What is rectification ? Explain the working of a full wave rectifier.

SECTION-C

III. Answer any TWO of the following LAQs: $2 \times 8 = 16$

19. (a) Explain the formation of stationary waves in an air column enclosed in open pipe. Derive the equations for the frequencies of the harmonics produced.

(b) A open organ pipe 85cm long is sounded. If the velocity of sound is $340\ ms^{-1}$, what is the fundamental frequency of vibration of the air column ?

20. State Kirchoff's law for an electrical network. Using these laws deduce the condition for balance in a Wheatstone bridge.

21. Explain the principle and working of a nuclear reactor with the help of a labelled diagram.

*****